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Team Knowledge Sharing Intervention Effects on Team Shared Mental Models and Team Performance in an Undergraduate Meteorology Course

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TEAM KNOWLEDGE SHARING INTERVENTION EFFECTS
ON TEAM SHARED MENTAL MODELS AND TEAM PERFORMANCE
IN AN UNDERGRADUATE METEOROLOGY COURSE

By

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ABSTRACT

Shared mental models (SMM) are defined as “knowledge structure(s) held by each member of a team that enables them to form accurate explanations and expectations for the [team and task], and in turn, to coordinate their actions and adapt their behavior to demands of the task and other team members” (Cannon-Bowers, Salas, & Converse, 1993, p. 228). Team member knowledge and perceptions about the team and tasks within a given environment is a main contributing factor for team effectiveness while SMM represents the commonality of this knowledge among team members (Cannon-Bowers & Salas, 1998).

There is evidence to support the link between SMM and team performance. Further, research has found that certain SMM based interventions can improve team processes ultimately leading to greater team performance. Though much of this evidence comes from high-stress / high-intensity (e.g. military) environments as well as in business, Mohammed and Dumville (2001) state that the team SMM framework can be applied across disciplines such as education where team learning strategies are used. The theoretical framework of SMM for analyzing and improving team performance has great potential for research and practical application in the academic environment. Despite this potential, there is limited empirical evidence to support the use of interventions designed based on the SMM framework in the academic setting where team learning strategies are being utilized.

The purpose of this study was to examine the effects of an SMM based intervention on team mental model similarity and ultimately team performance in an undergraduate meteorology course. The team knowledge sharing (TKS) intervention was designed to improve team and task-related knowledge sharing processes through promoting team reflection, communication, and improvement planning thereby enhancing SMM and ultimately team performance on meteorology lab assignments. The intervention targeted five critical SMM factors that are: general task and team knowledge, communication skills, attitude toward teammates and task, team dynamics and interactions, and team resources and working environment (Johnson et al., 2007).

This research involved conducting an experiment whereby 34 student teams in an undergraduate meteorology lab were randomly assigned to either a treatment or control condition. Prior to working on team lab assignments, teams in the treatment condition received the TKS intervention while those in the control condition received the non-SMM activity. Team-SMM
outcomes comprised two key elements: (1) content of team members’ perceptions regarding team and general task work as indicated by the Team Assessment Diagnostic Measure (TADM) mean and standard deviation (SD) scores and (2) the composition of team knowledge structures pertaining to team and general task work as indicated by the Team-SMM Structure score. Team-SMM content and structure are assessed within the context of teams working on three successive meteorology lab assignments. Team performance outcomes comprised team scores on meteorology team lab assignments 7, 8, and 9 as well as on a team quiz. MANOVA, ANOVA, and non-parametric statistical techniques were used to determine treatment and control group differences on the specified outcome variables.

The first theme of the study was concerned with examining the effects of the TKS intervention on Team-SMM. Significant differences were found between the treatment and control group on the following SMM related dependent variables: lab assignment 7 TADM SD score, lab assignment 8 TADM SD score and Team-SMM Structure score, and lab assignment 9 Team-SMM Structure score. The direction of these differences was consistent with the hypotheses. The second theme was concerned with examining the effects of the TKS intervention on team performance. Results revealed that lab assignment mean score was higher for the treatment group as compared to the control group though this difference was not significant. Lab assignment 8 mean score was significantly higher for the TKS treatment group as compared to the control group which supports the operational hypotheses. Lab assignment 9 mean score was significantly higher for the control group as compared to the treatment group which is in opposition to the operational hypothesis. The team quiz score mean was higher for the treatment group as compared to the control group which is consistent with the operational hypothesis.

Overall, the TKS intervention was effective as indicated by generally greater SMM and team performance for the treatment group as compared to the control. The TKS intervention could realistically be adopted for use in the MET 1010 course and similar academic settings to maximize the potential of student teams. Similar interventions could likely be developed, empirically examined, and potentially employed to promote success in handling complex challenges while working in teams in the classroom and beyond.
CHAPTER I: INTRODUCTION

Teams have been used within organizations in various sectors to accomplish valued goals and objectives. Teams are increasingly being used to solve complex organizational problems (Salas & Fiore, 2004), for improving quality and productivity, and even for managing entire operations (Proehl, 1997). Within the United States, 80 percent of organizations with 100 or more employees have assigned employees to working groups identified as teams. Among organizations with 10,000 or more employees this figure is closer to 90 percent (Proehl, 1997).

A team can be defined as “two or more individuals who must interact cooperatively and adaptively in pursuit of shared valued objectives” (Cannon-Bowers et al., 1993, p. 222). Team members take on specific roles, they are heterogeneous with regard experience, and they work together for a limited life-span (Cannon-Bowers et al., 1993). Often, team members have clearly defined and differentiated roles and responsibilities, hold task relevant knowledge, and are interdependent. Cannon-Bowers et al. (1993) state that this heterogeneity of expertise, roles, and responsibilities is what truly defines a team and differentiates them from groups.

Often organizations use the terms ‘group’ and ‘team’ interchangeably (Fisher, Hunter, & Macrosson, 1997). They generally define a work group or team as “a group of employees working towards a specific goal, interacting to share information about best procedures and practices, and making decisions which encourage all team members to perform to their full potential” (Mussnug & Hughey, 1997, p. 20). Despite an interchangeability of terms, Fisher, Hunter, and Macrosson (1997) found that groups tend to be affiliated with negotiating, networking, persuasion, and the sum of individual goals whereas teams are often perceived to be creative, innovative, well-rounded and working toward a unified goal.

Teams offer the advantage of using collective resources (knowledge, skills, and diverse expertise) to work on tasks that are too complex and/or too large to be handled by one person (Cooke, Salas, Kiekel, & Bell, 2004; Eccles & Tenenbaum, 2004; Stout, Cannon-Bowers, Salas, & Milanovich, 1999). Mathieu, Heffner, Goodwin, Salas, and Cannon-Bowers (2000) argue that technological advances within organizations have led to an increased complexity of on-the-job tasks, ultimately rendering it more difficult for people to work independently to achieve the performance objectives. Stout et al. (1999) state that in dynamic task settings, such as the aviation, nuclear power plant, and medical industries, teamwork is essential for successful job
completion. Even minor breakdowns in teamwork can result in dire consequences in such complex work environments where, at its extreme, error can result in loss of life.

Teams are also a powerful tool in promoting organizational effectiveness and achieving goals in the corporate setting (Guzzo & Dickson, 1996). In this context, teams are valued for such benefits as increased flexibility and creativeness as well as a diversity of perspectives that they bring. These teams are often self-directed in that they collectively manage themselves and their work to accomplish performance objectives. This framework is in contrast with the more hierarchical approach where a manager or leader directs and regulates the team processes (Clifford & Sohal, 1998; Polley & Ribbens, 1998). Though team error or failure in a corporate setting is not typically life threatening, it can result in a tremendous waste of resources. Thus, maximizing team potential and preventing failure are also critical in this context. Given that teams can impact the bottom line for many organizations, developing teams so that they can meet their expectations is operationally important.

By members sharing how and what they are thinking, teams are able to work together more effectively. This effect of team and task related knowledge sharing is represented in a theoretical framework for researching and improving team performance called shared mental models (SMM). SMM involves sharing knowledge structures regarding the team and task held by each team member (Cannon-Bowers et al., 1993). These shared knowledge structures or SMM allow team members to coordinate their actions and adapt their behavior given task demands as well as demands of working with other team members. Through SMM, teams are able to process complex information in order to draw inferences, make predictions, understand phenomena, decide what actions to take, control system execution, and experience events. SMM provide a functional means for teams to interact effectively with their environment (Cannon-Bowers et al., 1993).

Empirical evidence supports the notion that SMM is a valid predictor of team performance (e.g. Banks & Millward, 2007; Edwards, Day, Arthur, & Bell, 2006; Lee & Johnson, 2008; Mathieu et al., 2000; Stout et al., 1999). Further evidence suggests that certain interventions based on the SMM framework can enhance SMM and ultimately improve team performance (e.g. Gurtner, Tschan, Semmer, & Nägele, 2007; Marks, Sabella, Burke, & Zaccaro, 2002; Salas, Nichols, & Driskell, 2007; Smith-Jentsch, Zeisig, Acton, & McPherson, 1998; Stout, Salas, & Fowlkes, 1997).
In high-intensity and high-complexity environments, teams can approach tasks with collective knowledge that allows them to reach performance heights unobtainable by any one person. The same holds true for the corporate context where Dovey and Singhota (2005) suggest that “the team is [an] ideal structure for collective learning and knowing” (p. 18). That is, new knowledge can be acquired in a community where team-members become aware of gaps in their own knowledge and self-limiting mental-models, and team members can support each other to step out of their “comfort zones” to confront new challenges.

A number of performance improvement interventions, including training, have been designed in order to maximize team effectiveness. General team-building activities that are domain independent can be found on various websites and through such organizations as the American Society for Training and Development (Silberman & Phillips, 2005). Browsing the shelves of any local bookstore will turn up publications suggesting strategies for ‘getting the most out of your team’. Theoretically based and empirically tested strategies appear in various psychology, business, and communications journals (Groesbeck & Van Aken, 2001; Guzzo & Dickson, 1996; Kipp & Kipp, 2000; Proehl, 1997). One set of strategies stands out in its attempt to get teammates to share knowledge of working together as a team and about the task at hand. The general strategies that promote team and task knowledge sharing to improve performance are: cross-training (Volpe, Cannon-Bowers, Salas, & Spector, 1996), coordination and adaptation training (Cannon-Bowers & Salas, 1998), interaction training (Marks, Zaccaro, & Mathieu, 2000), self-correction training (Blickensderfer, Cannon-Bowers, & Salas, 1997), and guided reflexivity (Gurtner et al., 2007).

The SMM construct is essentially a representation of team member shared knowledge regarding task and team elements (Klimoski & Mohammed, 1994). Interventions designed from an SMM framework have been empirically shown to increase this shared knowledge and ultimately to improve team performance (e.g. Gurtner et al., 2007; Marks et al., 2002; Salas et al., 2007; Smith-Jentsch et al., 1998; Stout et al., 1997). Despite the findings regarding the advantages of using such interventions in organizational training and performance settings, the SMM framework has been sparsely applied to develop interventions within the academic setting when team learning strategies are being used. To perform well in an academic setting, students working in teams must acquire the necessary knowledge, skills, and attitudes (KSAs) to complete the required tasks while also understanding and anticipating the behaviors of each team.
member. Much like in the workplace, student teams engage in knowledge sharing processes to reach shared and valued goals (Johnson, Khalil, & Spector, 2008). Also like the workplace, student teams are faced with deadlines and are responsible for producing a final product though they are generally self-managed when it comes to completing tasks. Therefore, it is reasonable to expect that an intervention based on the SMM framework would have potential to improve the team member knowledge sharing process thereby increasing SMM and ultimately improving student team performance in an academic setting.

Research Problem

There is evidence to support the link between SMM and team performance (e.g. Banks & Millward, 2007; Edwards et al., 2006; Lee & Johnson, 2008; Mathieu et al., 2000; Stout et al., 1999). Further research has found that certain SMM based interventions can improve team processes ultimately leading to greater team performance. Though much of this evidence comes from high-stress / high-intensity (e.g. military) environments as well as in business, Mohammed and Dumville (2001) state that the team SMM framework can be applied across disciplines such as education where team learning strategies are used (Johnson et al., 2007). The theoretical framework of SMM for analyzing and improving team performance has great potential for research and practical application in the classroom environment where students work in teams. Despite this potential, there is no empirical evidence testing interventions designed based on the SMM framework in the academic setting where team learning strategies are being utilized. It is anticipated that a well designed intervention based on the SMM framework can improve student team performance in the learning environment.

Purpose of Study

The purpose of this study was to examine the effects of an SMM based intervention on team mental model similarity and team performance in an undergraduate meteorology laboratory course. The team knowledge sharing (TKS) intervention was designed to improve team and task-related knowledge sharing processes through promoting team reflection, communication, and improvement planning thereby enhancing SMM and ultimately team performance on meteorology lab assignments. The intervention targeted five critical SMM factors that are:
general task and team knowledge, communication skills, attitude toward teammates and task, team dynamics and interactions, and team resources and working environment.

This research involved conducting an experiment whereby student teams in an undergraduate meteorology lab were randomly assigned to either a treatment or control condition. Prior to working on team lab assignments, teams in the treatment condition received the TKS intervention while those in the control condition engaged in a non-SMM activity. The control activity covered the same amount of time as the team intervention but did not require any team activity related to the TKS intervention.

Team and task-related SMM outcomes comprise two key elements: (1) content of team members’ perceptions regarding team and general task work and (2) the structure or organization of team knowledge pertaining to team and general task work. Team-SMM content and structure are assessed within the context of teams working on meteorology lab assignments. Team performance outcomes comprise team scores on meteorology lab assignments as well as on a team quiz. By using a between groups experimental design, it was possible to compare the treatment and the control teams’ SMM and performance to determine the unique effects of the intervention. The following research questions provide the foundation for this study.

Research Questions and Themes

The general research question for this study is: what is the effect of a TKS intervention on team and task-related SMM and team performance in an undergraduate meteorology laboratory course? In order to answer the main question, there are four supporting research questions organized around two major themes.

**Theme 1: Effect of the TKS intervention on SMM**

*Supporting Research Question 1.1.* What is the effect of the TKS intervention on team and task-related SMM for specific meteorology lab assignments?

*Supporting Research Question 1.2:* Does the effect of the TKS intervention on team and task-related SMM vary depending on the number of previous team lab assignments?

**Theme 2: Effect of the TKS intervention on team performance in the MET 1010 lab**
Supporting Research Question 2.1. What is the effect of the TKS intervention on team lab assignment and quiz performance?

Supporting Research Question 2.2. Does the effect of the TKS intervention on team performance vary depending on lab complexity?

Significance of Study

Answers to the stated research questions will help determine whether an SMM based intervention can improve student team and task-related SMM and ultimately performance in an academic setting such as the MET 1010 laboratory course. The answers also provide evidence regarding the conditions under which the intervention is most effective given variations in the number of team lab assignments completed and the complexity of tasks that the team is working on.

This study is part of a larger body of research that seeks to apply the SMM construct to improve team performance in a variety of settings while addressing the need for empirical evidence regarding interventions to improve student team performance in a team-learning environment. If an intervention based on a sound theoretical framework such as SMM is found to be effective in this and similar studies, it could realistically be adopted for use in academic settings to maximize the learning potential of student teams. Similar interventions based on the SMM construct could then likely be developed, empirically examined, and potentially employed to promote success in handling complex challenges while working in teams both in the classroom and in the workplace. Chapter two provides a review of the literature detailing the SMM construct including SMM components, the link between SMM and team performance, and empirical evidence that interventions based on the SMM can improve team performance. The chapter concludes with the rationalization that the SMM framework has great potential for improving student team performance in the academic setting where team learning strategies are being used.
CHAPTER II: LITERATURE REVIEW

Organizations are harnessing the collective knowledge and skills of teams to perform tasks that may be too complex or too large to be handled by one person (Cooke, Salas, Kiekel, & Bell, 2004; Eccles & Tenenbaum, 2004; Stout, Cannon-Bowers, Salas, & Milanovich, 1999). Teams bring diverse perspectives to problems often leading to more effective and creative solutions than those generated by an individual (Guzzo & Dickson, 1996). Teams adapt their coordination and decision making strategies through closed loop communication and a sense of collective orientation to reach shared and valued goals. Teamwork involves members’ interdependent actions as they work together to achieve these shared and valued goals. Thus, teamwork is more than the work accomplished by a group of individuals; rather teamwork can be viewed as the result of collective cognitive, behavioral, and attitudinal activity during complex and dynamic interaction (Salas & Fiore, 2005). Team members each possess a knowledge set that allows them to perform their team tasks. When members contribute their unique knowledge, the team engages in a type of shared information processing that contributed to inter- and intra-individual outcomes. In other words, team member knowledge manifests itself in the form of a process (e.g. how to engage in team related tasks) as well as a product (e.g. memory for teammate capabilities) (Salas & Fiore, 2004, p. 4). The shared information processing and ensuing products provide the foundation for the SMM construct.

In high intensity / high complexity environments, such as the military, lives may depend on the effectiveness of team processes and performance. In a corporate setting, work team efficiency and effectiveness may directly impact the bottom line. Though effective team performance is critical in these environments, teams do not always work well together which can lead to a negative impact on performance. It is for this reason that team performance improvement interventions designed to promote team member knowledge sharing have been developed and evaluated. The aim of these interventions is to maximize the advantages of teams while limiting the propensity for error.

This chapter provides an overview of the SMM construct along with its components and ways to measure SMM. Empirical evidence supporting the link between SMM and performance is presented. SMM based interventions and how they have been empirically shown to improve team performance will be discussed. Finally, team learning in an academic setting is described while calling attention to the lack of evidence for using interventions to improve student team
performance when team learning strategies are employed. It is suggested that the SMM framework provides a viable means to design an intervention for improving student team performance within an academic setting.

Shared Mental Models

The SMM construct is subsumed within the broader framework of team cognition. Team cognition is the theoretical framework that describes the factors that play into a team’s ability to think (Salas & Fiore, 2004). The underlying assumption is that each team member possesses cognitions (e.g. thoughts, understandings, interpretations, beliefs, schemas, and mental models) regarding some aspect of the team’s work. It is the overlap or similarity of these understandings, beliefs, mental models, etc. that researchers can assess in order to understand what is “shared” by team members. Team cognition is more than the sum of the cognition of each individual within the team (Cooke, Salas, Cannon-Bowers, & Stout, 2000), as it emerges from the interaction of the individual cognition of each team member and team process. Within the team cognition model, the majority of research has focused on the sharing of mental models.

Individual mental models are schemata that not only represent one’s knowledge about specific subject matter, but also include perceptions of task demands and task performances. In general, mental models allow people to predict and explain system behavior as well as recognize and remember the relationship between system components and events (Klimoski & Mohammed, 1994). According to Johnson-Laird (1983), “people understand the world by constructing working models of it in their mind” (p.10) by way of knowledge that is organized into structured and meaningful patterns that are stored in memory. This enables people to process complex information in a rapid and flexible manner in order to draw inferences, make predictions, understand phenomena, decide what actions to take, control system execution, and experience events vicariously. Beyond the notion of schema, theorists contend that mental models can be modified, allowing people to predict system states via their understanding and shaping of model parameters. In sum, mental model functions provide a functional means for people to interact effectively with their environment (Cannon-Bowers et al., 1993).

Consistent with the mental model definition and framework, SMM are defined as “knowledge structure(s) held by each member of a team that enables them to form accurate explanations and expectations for the [team and task], and in turn, to coordinate their actions and
adapt their behavior to demands of the task and other team members” (Cannon-Bowers et al., 1993, p. 228). Team member knowledge and perceptions about the team and tasks within a given environment is a main contributing factor for team effectiveness while SMM represents the commonality of this knowledge among team members (Cannon-Bowers & Salas, 1998). Thus, it is suggested that a strong indicator of effective team performance is SMM – the degree to which members of a team hold similar conceptualizations of problems and approaches to solutions (Salas & Fiore, 2004). Simply stated, teams with members who think in similar ways about team and task processes and outcomes are likely to work effectively together and perform well.

Often the relationship between SMM and team performance is mediated by team processes. Klimoski & Mohammed (1994) state that SMM are an emergent characteristic of teams that influence both team processes (e.g. communication, conflict) and team outcomes (e.g. performance) (Edwards et al., 2006). The inputs-processes-outcomes (I-P-O) model (McGrath, 1984) has provided a systematic way of studying the relationship between team SMM and performance and how this relationship is mediated by team processes. Inputs to such models are conditions that exist prior to a performance episode and may include member, team, and organizational characteristics. Performance episodes are defined as distinguishable periods of time over which performance accrues and feedback is available. Processes describe how team inputs are transformed into outcomes such as through team information processing. Team processes are inherently linked to SMM especially in the areas of decision making and communication (Klimoski & Mohammed, 1994; Kraiger & Wenzel, 1997) as the team works together on tasks (i.e., performance episodes) (Mathieu et al., 2000). Outcomes are results and by-products of team activity that are valued by one or more constituencies. Three common types of outcomes are performance – including quantity and quality, team longevity, and members’ affective reactions (Mathieu et al., 2000). Figure 2.1 depicts the IPO model and its relationship to SMM modified from McGrath (1984) and Johnson et al. (2008).
SMM Components

A number of authors have detailed various components of the SMM construct as it relates to team and task-related knowledge in given situations or environments (e.g. Cannon-Bowers et al., 1993; Cooke et al., 2000; Fiore, Salas, & Cannon-Bowers, 2001; Klimoski & Mohammed, 1994; Mohammed & Dumville, 2001; Salas & Fiore, 2004). Cannon-Bowers et al. (1993) offered an early breakdown of SMM in identifying four components: task knowledge, equipment knowledge, team interaction knowledge, and team knowledge. Task knowledge is knowledge of task procedures, strategies, contingencies and scenarios, and environmental constraints. Equipment knowledge is knowledge regarding equipment functioning and limitations, operating procedures, and likely failures. Team interaction knowledge is knowledge of roles and responsibilities, sources of information, patterns of interaction and communication, and interdependencies among members. Finally, team knowledge is the knowledge of the KSAs and behavioral tendencies of team members. These elements are similar to Klimoski and Mohammed’s (1994) suggestion that team member shared knowledge of tasks, equipment, resources, strategies, goals, team members, and roles comprise their shared mental model.

An equally comprehensive, yet slightly different, description of SMM components was offered by Mathieu et al. (2000). According to the authors, SMM can be broken down into: technology / equipment knowledge, job / task knowledge, team interaction knowledge, and team
member knowledge. Team members must understand the technology and / or equipment with which they are interacting in terms of functioning as well as how the equipment interacts with the input of other team members. The technology / equipment SMM is likely to be the most stable in terms of content and probably requires less to be shared across team members. Team member shared job or task models are also important to performance in that they describe and organize knowledge about accomplishing the task in terms of procedures, task strategies, likely contingencies or problems, and environmental conditions. The value of shared task knowledge becomes increasingly more crucial as tasks become more unpredictable (Mathieu et al., 2000).

In order to be effective, team members must hold shared conceptions of how the team interacts. These models describe the roles and responsibilities of team members, interaction patterns, information flow and communication channels, role interdependencies, and information sources. Shared knowledge about team interactions drives how team members behave by creating expectations. Adaptable teams are those who understand well and can predict the nature of team interactions (Mathieu et al., 2000). Finally, the team member model contains information that is specific to the member’s teammates. Team member knowledge is crucial for team effectiveness because it allows team members to tailor their behavior in accordance with what they expect teammates to do. The more knowledge team members have about one another and the more accurate that information is the more efficient and automatic team processes can be (Mathieu et al., 2000). Similarly, Cooke et al. (2000) discuss task and team related knowledge as well as collective understanding of the current situation while Fiore et. al. (2001) cite knowledge of teammates’ roles, the team task, and potential situations that may be encountered as critical to team performance.

Though the above descriptions differ somewhat, team and task SMM are the common components making up the SMM construct within a given performance context. According to Cannon-Bowers and Salas (1998), team performance can be broken down into knowledge of both the task and team. In a study on SMM and performance, Mathieu et al. (2000) found that task and team mental models did not correlate significantly, therefore, it is reasonable to conclude that each type of SMM represents qualitatively different knowledge types.

Task SMM can be further broken down into task-specific knowledge and task-related knowledge (Cannon-Bowers & Salas, 2001). Shared task-specific knowledge allows team members to have compatible expectations of performance for a particular task thus decreasing
the need for team members to communicate overtly about the task. This type of knowledge can only be generalized to similar tasks. Task-related knowledge is knowledge of task-related processes that can be applied across a variety of tasks rather than knowledge of a specific task or related set of tasks. Drawing upon Mathieu et al.’s (2000) description of the SMM construct, team SMM can be broken down into *team interaction knowledge* and *team member knowledge*. Team interaction knowledge is the knowledge of roles and responsibilities, sources of information, patterns of interaction and communication, and interdependencies among members. This includes knowledge about teamwork processes which allow the team to be effective in accomplishing a variety of tasks (Rentsch & Hall, 1994). Team member knowledge concerns information that is specific to the member’s teammates – their KSAs, preferences, strengths, weaknesses, tendencies, etc. This is similar that Cannon-Bowers and Salas (2001) label as knowledge of teammates and has been studied within the transactive memory theoretical framework (Moreland, 2000).

A factor analysis conducted by (Johnson et al., 2007) revealed that team and general task SMM is made up of five factors. The factor analysis was conducted with 417 team members from four to five person in-tact teams working within private companies, federal government, non-profit organizations, and military organizations in the United States and Korea. Two-hundred and ten team members participated in the exploratory factor analysis (EFA) where they individually completed a 50-item team-related knowledge questionnaire. Five factors emerged as a result of the EFA which, based on the nature of the items within each factor and the literature review, the researchers labeled as: *general task and team knowledge, communication skills, attitude toward teammates and task, team dynamics and interactions, and team resources and working environment*. Two-hundred and seven different team members from in-tact teams then participated in the confirmatory factor analysis (CFA) where they completed a modified 42-item team related knowledge questionnaire. Results supported the validity of the five factor model. Each of the five team and task-related factors is discussed below.

*General task and team knowledge* covers task-related knowledge and the knowledge of general team processes that apply across a variety of tasks (Cannon-Bowers et al., 1993). *Communication skills* refer to the cognitive or physical abilities that are needed to engage in, practice, and communicate and coordinate action with teammates. This factor is consistent with Mathieu et al.’s (2000) team interaction knowledge. *Attitude toward teammates and task* is
concerned with the affective state that influences a team’s choices or decisions to act in a certain way under particular circumstances. This factor is consistent with Mathieu et al.’s (2000) team member knowledge.

*Team dynamics and interactions* go beyond team communication to include all teamwork processes and procedures while working on a given task, solving problems, making decisions, and adapting to new roles. Smith-Jentsch, Campbell, Milanovich, and Reynolds (2001) indicate that teamwork consists of four dimensions, including knowledge about: information exchange, dynamic interaction, supporting behavior, and guidance. This factor directly relates to Mathieu et al.’s (2000) team interaction knowledge. *Team resources and working environment* involves knowledge about the resources utilized by the team while working on a given task, as well as knowledge about the environment in which the task is being completed. This factor is most consistent with Cannon-Bowers et al.’s (1993) description of task-related knowledge where common knowledge about task processes is held across tasks rather than being related to one specific task. The breakdown of SMM components and the underlying five factors are presented in Figure 2.2.

![Figure 2.2. SMM components and the five factor model](image-url)
Theoretically, each of the five factors plays a role in defining SMM construct and predicting team performance. Johnson and Lee (2008) recently found that the five factors were strongly correlated with team and individual student performance in an online class that followed a team-learning approach. Given this link, the intervention used in this dissertation study will focus on team knowledge sharing relative to these five team and task related knowledge factors. An intervention based on this five factor model has not previously been developed and empirically evaluated in terms of its effects of SMM and performance.

Measuring SMM

Measures of SMM comprise both content as well as structure (Cannon-Bowers & Salas, 2001; Mohammed, Klimoski, & Rentsch, 2000). The content of SMM indicates the extent to which team members have common perceptions regarding teamwork and task work. SMM content measures can assess whether knowledge is shared, similar, complementary, and/or distributed (Cannon-Bowers & Salas, 2001). Measuring the components or content of a team’s SMM is generally done through elicitation techniques. Such techniques include: interviews, surveys, questionnaires, process tracing and protocol analysis (Cooke et al., 2000; Mohammed et al., 2000). Though elicitation data can be quantified to determine the similarity between team members, it does not tap into the underlying organizational structure of the team’s knowledge domain (Mohammed et al., 2000).

SMM structure represents the organization of the team members’ shared knowledge regarding teamwork and task work (Cannon-Bowers & Salas, 2001). Through elicitation techniques, individual ratings of the relationship between various team and task components are obtained from team members. Then, using representational techniques, the aggregated team structure of the relationship between team and task elements is determined (Mohammed et al., 2000). A popular representational tool is the Pathfinder program (Schvaneveldt, 1990) that uses an algorithm to connect components (nodes) through various paths. One similarity score is generated for the entire team which provides a quantitative index of the shared knowledge structure of that team.

Distinctions have been made between the collective and holistic approach for measuring SMM as well as between homogeneous and heterogeneous measures (Cooke et al., 2000; Cooke, Salas, Kiekel, & Bell, 2004). Consistent with the elicitation and representational techniques described above, the collective approach targets knowledge of individual team members then
quantitatively aggregates this information to determine content and structure. This aggregation method often focuses on the homogeneity of team member knowledge where it is assumed that *shared* knowledge among team members and *similar* knowledge among team members are essentially equivalent. The holistic approach assesses the team knowledge that emerges from team processes such as communication and situation assessments through qualitative means (Cooke et al., 2000). This holistic method has potential for understanding the more subtle aspects of team knowledge sharing as teams work together on tasks. Also, unlike typical aggregation methods, the holistic approach accounts for the heterogeneous cognition that takes place within a team as the result of members taking on different roles (Cooke et al., 2004). Despite the potential of holistic measures of team knowledge sharing, the collective approach remains a valid means for measuring SMM construct and its ability to explain and predict team performance (Cooke et al., 2000). Thus, the collective approach will be used in this study to understand the homogeneity of team member knowledge through aggregation measures that capture SMM content and structure immediately following each performance episode.

The SMM construct provides a framework for understanding how teams interact and process information while working on tasks. Despite the somewhat different descriptions of SMM components provided by various authors, the general components of team SMM and task SMM are consistent across each of these descriptions. Measuring SMM can be accomplished through elicitation and representational techniques to determine content and structure. Reliable and valid indicators of team and task SMM provide a window to explaining and predicting team performance. The next section describes the empirical evidence linking SMM to performance outcomes.

**SMM and Team Performance**

Research supports the empirical link between SMM and effective team performance (e.g. Blickensderfer, Cannon-Bowers, & Salas, 1999; Cannon-Bowers & Salas, 2001; Cannon-Bowers et al., 1993; Cooke, Gorman, Duran, & Taylor, 2007; Lim & Klein, 2006; Mathieu, Heffner, Goodwin, Cannon-Bowers, & Salas, 2005; Mathieu et al., 2000; Salas & Fiore, 2004). It is suggested that SMM enhance the quality of teamwork skills and team effectiveness. ‘The greater the overlap or commonality between team member’s mental models, the greater the likelihood that team members will predict the needs of the task and team, adapt to changing demands, and
coordinate activity with one another successfully” (Klimoski & Mohammed, 1994, p. 412). Team members who share mental models of the task and team can better anticipate behavior and resource needs of their fellow members.

The SMM construct can be a powerful explanatory mechanism, a predictive variable, and a diagnostic tool in terms of team performance (Cannon-Bowers & Salas, 2001). By way of an explanatory mechanism, observations reveal that members of effective teams share knowledge in a way that enables them to interpret cues in a similar manner, make compatible decisions, and take appropriate action (Cooke et al., 2004; Klimoski & Mohammed, 1994; Mohammed & Dumville, 2001; Smith-Jentsch et al., 2001). In understanding SMM, it is then possible to predict a team’s readiness or preparedness to take on a task and ultimately to predict the team’s likely effectiveness. Finally, in understanding the elements of effective teamwork, practitioners can use the explanatory and predictive power of SMM to diagnose problems within teams and gain insight for interventions that address these problems and improve team performance (Cannon-Bowers & Salas, 2001).

Several empirical studies have examined the relationship between SMM and team performance. In a recent field study, Lim and Klein (2006) found that team and task mental model similarity were valid predictors of team performance among 71 armed forces combat teams. The relationship between SMM and performance was direct, as was the relationship between mental model accuracy and performance. Lim and Klein (2006) suggest that the direct link between SMM (both task and team) and performance is due to the fact that the teams examined in the study were expected to perform in high stress environments under intense time pressure on a regular basis. In this type of environment, SMM are theorized to have the greatest predictability for team performance given that there is little time for explicit coordination and communication (e.g. Klimoski & Mohammed, 1994; Salas & Fiore, 2004).

In a repeated measures study guided by the I-P-O framework, Heffner (1998) found that greater team and task SMM among two-person teams led to better performance on a flight simulation task. This relationship was mediated by the quality of team processes. Also using the I-P-O framework as a guide, Mathieu et al. (2000) examined team and task SMM and their relationship with team processes and performance on a low-fidelity flight simulation for 56 two-person teams. Team mental model convergence correlated significantly with process quality and performance for some of the performance sessions but not all (Mathieu et al., 2000). Task mental
model convergence did not correlate significantly with team process quality nor team performance. The authors conclude that the findings of this study support the construct validity of SMM for predicting the quality of team processes and ultimately performance (Mathieu et al., 2000).

The above study (Mathieu et al., 2000) was replicated by Mathieu, Heffner, Goodwin, Cannon-Bowers, and Salas (2005) and was extended it to include team mental model quality. Team mental model quality was defined as how closely the teams’ mental models aligned with a normative model generated from subject matter experts in the area of team research. The major difference in the replication study results was that “team SMM had no significant linear relationship with either team processes or performance” (Mathieu et al., 2005, p. 51) yet task SMM was shown to have not only a strong relationship with team process but also with team performance. These findings were supported by Stout, Cannon-Bowers, Salas, and Milanovich (1999) who found that effective planning processes were related to task SMM and team performance in a high-workload task scenario. The Stout et al. (1999) study, however, focused solely on task SMM and did not measure the relationship between planning processes, team SMM and performance outcomes. The findings from both studies (Mathieu et al., 2005; Stout et al., 1999) are supported by Lee and Johnson (2008) who found that task SMM, when compared to team SMM, was the better predictor of team performance among engineering student teams.

An interesting finding in the Mathieu et al. (2005) study was that SMM had a strong relationship with team mental model quality which was ultimately beneficial to team processes. Given that team process had a high positive correlation with team performance, it is likely that the impact of team SMM on performance is mediated by the quality of the team mental model as well as team processes. Further, team processes suffered when team mental models were of high-quality but with low sharedness. The authors suggest that this is a situation where team members have their own understanding for what must be done but disagree on how to do it. Though the findings do not provide evidence for a linear relationship between team SMM and process or performance, team SMM appear to be indirectly responsible for predicting such outcomes.

While further research is necessary to determine whether team SMM or task SMM is the better predictor of team performance, each has been found to have explanatory and predicative validity in various studies. Consistent with the I-P-O model, the relationship between SMM and performance is often mediated by team processes. Given the link between SMM and
performance, researchers have begun to develop interventions based on the SMM framework that attempt to improve team performance by targeting team processes linked to the SMM construct. This makes use of the SMM construct as not only an explanatory and predictive mechanism but also one that has power to correct and enhance team performance (Cannon-Bowers & Salas, 2001).

SMM Interventions and Team Performance

SMM have great value in terms of explaining team processes and predicting team performance. SMM allows team members to coordinate their actions and adapt their behavior given task and team member demands (Cannon-Bowers et al., 1993). Team member shared knowledge is crucial for team effectiveness because it allows team members to tailor their behavior in accordance with what they expect teammates to do. Practically, SMM “research can help establish an understanding of the elements of effective teamwork, which can in turn lead to better interventions for improving team performance” (Cannon-Bowers & Salas, 2001, p. 196).

This section describes a number of interventions that, based on the relationship between SMM, processes, and performance, are designed to enhance team processes related to SMM development in order to improve team performance. These interventions include: team cross-training, team coordination and adaptation training, team interaction training, team self-correction training, and guided team reflexivity. Though there are a number of interventions designed to improve team performance, this section represents the body of empirical evidence supporting the notion that interventions based on the SMM framework can enhance mental model similarity and ultimately improve team performance.

One means to get team members to share knowledge regarding team and task elements is team cross-training. Team cross-training is “an instructional strategy in which each team member is trained in the duties of his or her teammates” (Volpe et al., 1996, p. 87). More specifically, cross training involves team members rotating roles or positions in order to gain the knowledge required for other team members to perform their tasks. It also gives team members a better understanding of how each member’s role is important in accomplishing team objectives (Cannon-Bowers & Salas, 1998). It is expected that, by introducing team members to the roles and responsibilities of their teammates, mental model similarity will increase thereby improving team coordination and ultimately team performance (Marks et al., 2002). One key assumption for
this intervention to be effective is that team members each have unique roles. This unique roles assumption is consistent with Cannon-Bowers et al.’s (1993) definition of ‘team’.

Marks et al. (2002) examined the efficacy of cross-training by administering the strategy to nearly 100 three-person undergraduate student teams. Members of each team were trained in their own roles as well as in the roles of each teammate for performing a PC flight or tank simulated mission. Results of two experiments described in the paper revealed that cross-training facilitated the development of team interaction mental models. Also, team coordination processes fully mediated the relationship between shared team-interaction models and team performance (Marks et al., 2002). The more in-depth form of cross-training (i.e., team members were able to practice working in each role) used in the second experiment created a higher degree of SMM when compared to cross-training that simply generated awareness about or modeled the various roles. The experiments provide solid evidence that cross-training is an effective means for increasing the similarity of team interaction mental models, improving team coordination processes, and ultimately improving team performance (Marks et al., 2002).

It has been asserted that communication processes, strategy and coordinated use of resources, and interpersonal relations or cooperation are important factors in linking SMM with team performance (Klimoski & Mohammed, 1994). Team coordination and adaptation training is one strategy that has addressed this assertion. This strategy is aimed at improving teamwork during periods of high-stress by teaching team members to alter their coordination strategy and reduce the amount of extraneous communication associated with performing a given task (Entin & Serfaty, 1999). This extraneous communication, otherwise labeled ‘communication overhead’, is expected to diminish as teams develop their SMM (Cannon-Bowers & Salas, 1998; MacMillan, Entin, & Serfaty, 2004).

A study conducted by Entin and Serfaty (1999) found that Navy officer teams that were given adaptation and coordination training exhibited significantly better teamwork and performance on a flight simulation mission when compared to the control group that received general training. Though SMM was not measured in this study, the authors assert that the improved situational SMM led to more effective coordination and ultimately better team performance among the coordination and adaptation training group. The findings that team adaptation and coordination training can significantly improve both teamwork skills and task performance supports the assertion that the dual concepts of SMM and adaptive coordination are
a productive approach for understanding and developing effective teamwork (Entin & Serfaty, 1999).

Also targeting member cooperation, interpersonal relations, and communication processes to improve team performance (Klimoski & Mohammed, 1994) is team-interaction training. **Team-interaction training** is defined as “the training of task information embedded in the necessary teamwork skills for effective team task execution. The content of this training refers to how to work better as a team, not how to perform the task requirements better per se” (Marks et al., 2000, p. 974). This strategy is critical in preparing teams to respond effectively in novel and dynamic task environments.

To test the effectiveness of team interaction training, Marks et al. (2000) trained three-person undergraduate teams how to coordinate their actions while engaged in a war game simulated mission. After completing the mission, each team member created a concept map that represented the best course of action for each team member during the simulation. Teams that received interaction training showed greater SMM and mental model accuracy compared to the control group. Performance was also greater among teams that received the training while the relationship between SMM and performance was partially mediated by communication processes (Marks et al., 2000). The authors conclude that SMM plays a vital role in adapting to novel environments and that team interaction training is a useful tool for developing SMM and promoting effective performance is such environments.

**Team self-correction training** is another intervention for developing SMM and promoting effective performance and is based on the idea that intra-team feedback can foster greater SMM and improve team performance. In this strategy, team members give each other feedback about how they are performing the task and the underlying expectations for performance to help foster similar and correct expectations about team and task work (shared and accurate mental models) among team members. This feedback can also facilitate modifications for incorrect and dissimilar expectations (Blickenstorfer et al., 1997). In team self-correction training, teams are provided with strategies that allow them to evaluate their own performance, diagnose root causes of performance problems, identify solutions, and plan for future tasks (Smith-Jentsch et al., 1998).

A study conducted by Smith-Jentsch et al. (1998) found that a specific form of team self-correction training called team dimension training (TDT) led to increased similarity of teamwork
mental models among shipboard instructor teams. Instructor performance ratings also revealed that TDT aided teams in diagnosing team problems, focusing their practice on specific goals, and generalizing lessons learned (Smith-Jentsch et al., 1998). The TDT training was delivered to numerous teams as part of the required curriculum over a three year period in the form of a one-day workshop. Thus, it is difficult to isolate the direct effects of the training on SMM and performance.

In a later study, Smith-Jentsch et al. (2001) examined the effects of computer based self-correction training on teamwork mental model accuracy and similarity among 42 civilian government employees. Results revealed that after progressing through the training, participant’s teamwork mental models were more aligned with the expert model (i.e., more accurate) as well as more similar to one another. Trainees were also more consistent in their mental model representation following the training session. It is important to note, however, that participants did not work in teams nor interact with one another at all during this study. Rather, the teamwork mental model accuracy and similarity was elicited based on individual self-correction training relative to a predetermined expert model. Given this approach, it was also not possible to examine team performance relative to SMM and mental model accuracy (Smith-Jentsch et al., 2001).

*Guided team reflexivity* is a similar strategy to team self-correction training designed to induce reflection in groups. This strategy asks teams to reflect on their performance so far, to consider potential improvements, and to develop plans for how the improvement strategies should be implemented (Gurtner et al., 2007). The new strategies are then implemented through action or adaptation. Gurtner et al. (2007) found that guided team reflexivity enhanced the similarity of the team interaction mental models, generated more effective team communication processes, and ultimately improved team performance on a military air-surveillance simulation.

Based on the empirical evidence, each of the above strategies is likely to increase SMM and improve team performance in a variety of cases. A recent meta-analysis conducted by Salas, Nichols, and Driskell (2007) found that there was a small-to-moderate tendency for team training to result in greater team performance when compared with the control conditions. The meta-analysis included only studies that involved administration of some degree of cross training, team coordination and adaptation training, and/or team self-correction training. Team coordination and adaptation training was found to have the greatest benefits for improving team
performance when compared to control groups (Salas et al., 2007) though more research is needed to determine when each strategy is best applied across a variety of contexts outside of a research lab setting.

The common element among the previously discussed interventions is that they are designed to enhance team processes related to SMM development in order to improve team performance. The next section provides an overview of team learning in an academic context. Based on the similar characteristics between the educational and workplace environments, it is possible to draw a number of the elements from the strategies detailed above to develop an intervention that can improve student team performance.

The TKS intervention used in this dissertation study is designed to promote team member knowledge sharing relative to five team and task-related knowledge factors. Teams will go through a process that is most consistent with the team reflexivity, interaction training, and team self-correction interventions described above. Specifically, team members will engage in (1) individual reflection regarding team and task related knowledge, (2) discussion of team and task-related knowledge, and (3) discussion and documentation of ways to improve on specific team and task-related knowledge areas. Similar to the above interventions, the goal is to enhance team SMM and ultimately team performance by targeting the team knowledge sharing process. The theoretical foundation of the TKS intervention and its practical impact on SMM and ultimately team performance is presented in Figure 2.3.

![Figure 2.3. Theoretical basis and practical impact of the TKS intervention](image-url)
The next section describes three main team learning strategies and the potential for applying the TKS intervention in an academic setting where such strategies are being utilized.

SMM and Team Learning Strategies

There is substantial evidence to verify that SMM can be a valid explanatory, predictive, and corrective mechanism for performance in a workplace context. The same evidence is limited, however, in the academic setting for student teams where similar skills and knowledge sharing processes apply (Johnson et al., 2008). Much like in the workplace, student teams in higher education must manage themselves in performing tasks within a given time period. Often the tasks in the academic setting are complex enough that students can accomplish more by working as a team versus working on these same tasks individually. In order to be successful in working in teams on such complex tasks, students must acquire the knowledge and skills to perform the necessary tasks while also understanding and anticipating the behaviors of each team member. A recent study conducted in an online course by Johnson and Lee (2008) found that team’s SMM changed significantly over time as teams participated in team learning activities. From an organizational standpoint, having students work in teams can allow higher education institutions to achieve the shared and valued goal of teaching ever increasing numbers of students without substantially increasing the burden on faculty (Johnson et al., 2008).

Team learning is consistent with the theoretical traditions of situated cognition (Lave & Wenger, 1991), developmental and international theories (Piaget, 1972; Vygotsky, 1978), and more recently constructivism (Bruner, 1990; Vygotsky, 1986). The common element between these theories is that learning takes place in a social context where interaction and authentic experience are critical (Driscoll, 2000). Drawing upon these theoretical traditions, there are three general instructional strategies that have received attention for their use of groups or teams in an academic setting: cooperative / collaborative learning (Slavin, 1987, 1996), problem based learning (Barrows, 1998; Barrows, 2000; Savery & Duffy, 1995), and team based learning (Michaelsen, Knight, & Fink, 2002). The three main team-learning strategies are described below and summarized in Figure 2.4.

**Collaborative / cooperative learning** (Slavin, 1987, 1996) involves the frequent use of carefully planned and carefully structured group activities that are inserted into pre-existing course materials. By working in teams, students are able to handle complex assignments more
effectively while enhancing their learning through peer interaction. There is a high consideration of group member accountability issues, group formation, and student roles but this approach does not necessitate changing the course structure. That is, the focus remains on assignments and learning outcomes with somewhat less of a consideration for team processes (Michaelsen et al., 2002). Cooperative learning has been examined from a variety of perspectives including: motivational, social cohesion, cognitive, and developmental (Slavin, 1996). Since the 1970s, research has found cooperative learning to be a useful tool for promoting student learning (Johnson & Johnson, 1999; Slavin, 1987, 1996). For example, Holubec, Johnson, and Johnson (1993) found that a Navy traffic controller trainee class where cooperative learning was used showed greater job functioning ability when compared to 50 other classes that used more traditional instruction.

Problem-based learning (PBL) involves students working in teams to solve carefully designed ill-structured problems that represent real world scenarios (Barrows, 1998; Barrows, 2000; Savery & Duffy, 1995). In collaborating to solve authentic problems, students are able to share their ideas while also being exposed to others’ perspectives. This promotes the development of students’ problem-solving strategies, disciplinary knowledge, and skills associated with working in a team. Thus, PBL is as much concerned about the knowledge sharing process surrounding the ill-structured problem as it is about learning outcomes. The problem and the team are at the center of this process while the instructor acts as a facilitator and a guide. A meta-analysis carried out by Dochy, Segers, Van den Bossche, and Gijbels (2003) found PBL to be a useful strategy for developing student problem-solving skills and knowledge though the effects on these outcomes were generally moderated by level of student expertise, retention period, and assessment methods (Dochy et al., 2003; Gijbels, Dochy, Van den Bossche, & Segers, 2005).

Team-based learning (TBL) is an instructional strategy that makes small group-work the primary class activity. It calls for procedures that support the transformation of “newly formed groups” into “high-performance teams” (Michaelsen et al., 2002). Teams will generally remain together for the duration of a semester or unit of instruction collaborating on a number of assignments and tests. Much time is spent on assuring team readiness through assessment, team planning, and the negotiation even before students begin class activities. The suggested benefits of team-based learning include positive effects on academic achievement, efficient use of
instructional time, increased peer interaction, improved interpersonal relationships, and transfer of skills (Michaelsen et al., 2002).

In a study in a microbial physiology course, McInerney (2003) found that TBL significantly improved student comprehension, retention, and critical thinking as well as student attitudes about the course. Similarly, Kuhne-Eversmann, Eversmann, and Fischer (2008) found that when using a cased-based design that followed the team learning concept in a course on internal medicine, students showed significant increases in their knowledge from the course outset. Students also rated the course as “highly instructional”, indicating that they were motivated to participate and their expectations were fulfilled (Kuhne-Eversmann et al., 2008). Though TBL is fairly new, it appears to have promise as a powerful instructional strategy for promoting learning and group development (Sweet & Michaelsen, 2007).

![Figure 2.4. Team learning strategies with definitions](image)

Team learning strategies such as cooperative / collaborative learning, PBL, and TBL have the potential to promote student knowledge sharing. Also, working in teams allows students to handle complex tasks in a short time period rather than struggling on their own. Finally, team
learning strategies can prepare students to work with peers in other learning situations and eventually in the workplace. Research has found that the specific benefits of these strategies include: positive effects on academic achievement and knowledge retention, efficient use of instructional time, increased peer interaction, improved interpersonal relationships, development of critical thinking skills, and generalization of skills to other settings (e.g. DeVries, Mescon, & Shackman, 1976; Dochy et al., 2003; Druckman & Bjork, 1994; Elbaum, Moody, Vaughn, Schumm, & Hughes, 1999; Holubec et al., 1993; McInerney, 2003; Slavin, 1996). One must consider, however, that for any instructional approach, including team learning, to be effective it is important for the instructor to have a clear understanding of the learning environment, performance task characteristics, and learner characteristics. Through environmental, task, and learner analysis it may be determined that an individual approach to instruction will be more beneficial for closing the knowledge gap. If that is the case, the above benefits will likely be diminished and team learning could possibly have a detrimental effect on learning outcomes.

Team learning can be a powerful instructional approach with a number of advantages when used appropriately. Though team and task-related processes are an integral part of the previously described strategies, especially PBL and TBL, there is little empirical research for how to target these processes in order for students to work more effectively as teams. The SMM framework has great potential for researching and developing interventions to improve team processes and ultimately performance in the academic environment where team learning strategies are being employed. Johnson et al. (2008) state that it is important for faculty using team learning to help teams develop their interaction strategies especially when the level of SMM are low or when communication breaks down. One specific means suggested is to “encourage students working in teams to discuss the various factors of SMM including both team knowledge as well as task knowledge” (Johnson et al., 2008). In response to the authors’ suggestion, this study aims to test the effectiveness of an intervention in an undergraduate meteorology lab course (MET 1010) that uses a team learning approach. In MET 1010, students work as teams throughout the semester on various lab tasks that involve the application of knowledge and skills to solve complex real world meteorology problems. Student teams in the MET 1010 lab that receive the intervention will be encouraged to share their team and task-related knowledge in the context of working on lab assignments. It is expected that the TKS
intervention applied in the MET 1010 team learning environment will enhance SMM leading to better performance among student teams.

Summary

SMM is a theoretical construct that represents knowledge held by each team member allowing the team to think about team and task elements within the performance context. Team SMM and task SMM are the two main components making up the SMM construct. Task SMM comprises task-specific knowledge and task-related knowledge while team SMM comprises team interaction knowledge and team member knowledge. Team and task-related SMM consists of five unique factors including: general task and team knowledge, communication skills, attitude toward teammates and task, team dynamics and interactions, and team resources and working environment. Measures seek to assess the content of SMM through elicitation techniques as well as the structure of SMM through representation techniques. These measures rely on an aggregation of team member team and task knowledge to better explain and predict team processes and performance.

Evidence from field and lab studies provides support for the theoretical link between SMM and team performance. Many of these studies have also found that team processes often mediate the relationship between SMM and performance. Interventions based on the SMM framework have been successful in improving both team processes and performance. These interventions include: team cross training, team coordination and adaptation training, team interaction training, team self-correction training, and guided team reflexivity. Despite the ability of SMM interventions to improve team performance in the workplace context, these same types of interventions have not been applied among student teams in an academic setting where similar processes and outcomes apply.

Team learning strategies such as cooperative / collaborative learning, PBL, and TBL have been found to promote the development of student KSAs in terms of both team and task elements. Team learning can also allow educational institutions to teach large numbers of students despite limited resources. Research in the area of team learning generally compares these strategies to a more traditional form of instruction without examining means for improving team processes to promote learning and performance. This study addresses this gap by examining the effects of an intervention that promotes team reflection, discussion, and planning regarding SMM in order to
improve team SMM and ultimately team performance in the MET 1010 team learning environment. The next section details the methods used in conducting this study.
CHAPTER III: METHODS

The purpose of this study was to examine the effects of applying an intervention based on
the SMM construct to improve student team performance in an undergraduate meteorology lab
course. The intervention promoted team reflection, communication, and planning relative to five
critical SMM factors including: general task and team knowledge, general task and
communication skills, attitude toward teammates and task, team dynamics and interactions, and
team resources and working environment. This study used a between groups experimental design
with a treatment condition and control condition. Prior to working on team lab assignments,
teams in the treatment condition received the TKS intervention while those in the control
condition engaged in a non-SMM control activity. The control activity covered the same amount
of time as the team intervention but did not require any team interaction or deal with SMM in
any way. By using a between groups experimental design, it was possible to compare the SMM
and performance of the treatment group to the control group thereby determining the unique
effects of the intervention. This chapter presents the details about the participants and
meteorology lab course setting, the TKS intervention and control tasks, team assignments and
quizzes, instrumentation, data collection procedures, and data analysis strategies.

Participants and Setting

Participants for this study were 112 undergraduate students (34 teams) enrolled in MET
1010: Introduction to Meteorology Laboratory. Students from a wide variety of academic
programs such as communication, sports management, theatre, and business were enrolled in the
lab in order to meet the science credit requirement for first-year students. Results of the
demographic survey (Appendix F) revealed that 11.6 percent of the participants were
Meteorology majors while 19.6 percent of the total participants self-reported that they had
previous experience with meteorology concepts beyond the MET 1010 course.

Participants’ age ranged from 18 to 25 years with a mean age of 19.15 years. Forty-four
point six percent of the participants were male and 55.4 percent were female. Eighty-two point
one percent of the participants were Caucasian, 8 percent were Hispanic, 8 percent were Black,
and 1.3 percent were of another non-specified race. Participants’ self-reported skill level with
MET 1010 lab assignments tasks was measured on a scale from 1 (very low) to 5 (very high).
Participants’ mean score on this scale was 2.98 with a standard deviation of 0.75 indicating a
medium perceived skill level. Based on conversations with the teaching assistants and head
course instructor, it was determined that these demographics represent a typical first year
undergraduate Meteorology lab course. Also, the age, gender, and race distribution is
representative of the first-year undergraduate student cohort at Florida State University ("FSU
Student Profile: Student Demographics," 2007).

In terms of teamwork, 86.6 percent of the participants reported that they had no previous
experience working with their team members outside of MET 1010 lab and 95.5 percent of the
total participants reported that they had no previous experience working with their team
members within MET 1010 lab. Participants’ mean self-perceived ability to work in a team as
measured on a scale from 1 (very low) to 5 (very high) was 4.05 which indicates that participants
perceive themselves to have a high ability to work in a team. Participants’ mean team-member
perceived ability to work in a team as measured on a scale from 1 (very low) to 5 (very high) was
3.86 which indicates that participants perceived their teammates ability to work in a team as
medium to high. When asked about team member skill level on Meteorology lab assignment
tasks, 85 percent reported that their teammates were at a medium skill level or above.

MET 1010 lab is offered at Florida State University every semester with this dissertation
study taking place during the 2008 fall semester. There were nine lab sections offered Monday
through Friday over the 14-week semester. Each lab section met once per week for a total of 14
lab sessions per section over the duration of a semester. The number of students enrolled in each
lab section varied with a minimum enrollment of eight students and a maximum of 19 students in
a given section. Two of the teaching assistants taught two sections while the others taught only
one section. The content covered in each session is based on the MET 1010 laboratory manual
(Ruscher & Stephens, 2005) and was generally consistent across all sections.

The main reason for choosing to conduct this study in the MET 1010 course was that
team assignments are built into the course with at least 50 percent of the labs requiring students
to work in teams and submit one completed lab assignment per team. Another reason for
choosing the MET 1010 course was the complex nature of the lab tasks. Each lab requires
conceptual knowledge and the ability to apply this knowledge to solve a problem (e.g. using a
tracking map to plot and track hurricanes). Finally, when conducting team studies, the unit of
analysis is the team which substantially reduces the $n$ therefore MET 1010 lab was chosen due to
the high number of students enrolled during the fall semester.
Intervention and Control Tasks

The TKS intervention was administered to all teams in the treatment condition before labs 7, 8, and 9 for a total of three intervention points. The intervention consists of a three parts designed to promote reflection, communication, and improvement planning relative to the SMM framework. This intervention draws elements from a number of SMM intervention strategies, particularly: guided team reflexivity (Gurtner et al., 2007), coordination and adaptation training (Cannon-Bowers & Salas, 1998), interaction training (Marks et al., 2000), and team self-correction training (Blickensderfer et al., 1997). Part I of the intervention involved team members reflecting upon and rating their team on team and task-related knowledge factors identified by Johnson et al. (2007). Part II involved team members having to reach a consensus by rating the same factors as a team. Part III asked the team to identify the top two areas where they can improve and to discuss and write-down how they can improve in each of the identified areas. This reflection, discussion, and strategizing was directly related to team processes as teams worked on meteorology laboratory assignments. Theoretically, this type of intervention was designed to elicit more similar and greater team SMM and ultimately better team performance for the treatment group. See Appendix A for the intervention instructions.

Teams in the control condition participated in a newspaper article task before labs 7, 8, and 9 for a total of three separate news article tasks (a different article before each lab). The task required individual students to read a news article on the topic of weather prediction myths. After completing the article students individually answered two questions pertaining to the article’s content. Teams were required to write down their short answer responses to the questions. The goal was to have students engage in a meaningful task related to meteorology that did not involve the discussion of SMM or content directly related to the lab assignments. See Appendix B for the control task newspaper articles and questions.

Team Lab Assignments and Quiz

MET 1010 lab is composed of 14 lab assignments with team lab assignments occurring during 7 of the 14 sessions. Team lab assignments 3, 4, and 5 consist of foundational meteorology information that requires students to work in teams to generate some basic calculations and observe general weather patterns such as temperature and humidity. Lab assignments 7, 8, and 9 involve teams applying the foundational knowledge to predict and track
weather phenomena such as hurricanes and El Niño and to conduct upper air observations. Lab assignment 12 involves students working in teams to generate dynamic forecasts while factoring in a time element. Lab assignments 7, 8, and 9 were the focus of this study since they formed a cohesive set of team lab assignments where the TKS intervention was applied. See Appendix C for lab assignments 7, 8, and 9.

To provide the researcher with a better understanding of the nature of the lab assignment tasks, the MET 1010 teaching assistants were asked to rate the team lab assignments in terms of Steiner’s (1972) task typology. The teaching assistants were presented with definitions of unitary and divisible tasks consistent with those proposed by Steiner. They were then asked to rate each of the lab assignments on a ten-point scale from 1 (unitary) to 10 (divisible) based on their experience teaching the labs and the task descriptions in the MET 1010 lab manual. See Appendix D for the full teaching assistant lab rating instrument.

Complete responses were gathered from the four active (i.e., presently teaching) teaching assistants. Lab assignment 7 was given a mean rating of 7.25 and lab assignment 8 was given a mean rating of 8.50. This indicates that the teaching assistants perceived the tasks for these two labs to be more divisible in nature. Conversely, lab assignment 9 was given a mean rating of 3.5 indicating that the teaching assistants perceived this lab to be more unitary. Finally, lab assignment 12 was given a mean rating of 6.5 which was once again closer to the divisible end of the scale.

Finally, teams completed one team quiz assessing their knowledge of material covered in lab assignments 7, 8, and 9. The quiz required team members to reach a consensus on responses to true or false, multiple choice, and short answer questions. Teams submitted only one quiz per team. The quizzes were administered to the teams the week following their completion of lab assignment 9. See Appendix E for the team quiz.

Instrumentation

The next section describes the data collection instruments necessary for answering the research questions as well as gathering information about the study participants and lab assignment tasks.
Demographics

A demographic survey (see Appendix F) was administered during the second lab session prior to participants beginning any team lab assignments. This survey included questions regarding participant’s background information (e.g. age, gender, race, year in school) and was also used to gather information about participants’ previous experiences with meteorology lab related tasks as well as prior experience working in teams.

Lab Assignment Characteristics Questionnaire

After every team lab assignment, participants were asked to complete a lab assignment characteristics questionnaire. The goal of the questionnaire was to provide a subjective measure of student perceptions regarding lab assignment complexity in order to determine if the effect of intervention on team performance depended on the perceived complexity of the lab assignment tasks. Rather than asking one complexity question, several items thought to be related to the notion of complexity were included such as difficulty, workload, stress level, etc. This allowed for reliability testing which would not have been possible with a one item measure. It also helped to determine whether difficulty and complexity are two distinct constructs (Robinson, 2001) and whether complexity was related to the variety of tasks to be completed (Stout et al., 1997). The questionnaire asked individual participants to rate six items on a five-point scale ranging from strongly agree to strongly disagree. The specific items were:

1. The lab assignment we just submitted was complex
2. Working on the lab assignment we just submitted was stressful
3. The lab assignment we just submitted was difficult for me
4. The amount of work was high for the lab assignment we just submitted
5. The lab assignment we just submitted was mentally challenging
6. A wide variety of tasks had to be completed for the lab assignment we just submitted

Reliability analysis of the lab assignment characteristics scale revealed a Cronbach’s alpha statistic of .867. Table 3.1 presents the lab assignment characteristics questionnaire inter-item correlations. The lowest inter-item correlations were with item six “a wide variety of tasks had to be completed for the lab assignment…” which indicated that students did not necessarily equate variety of tasks to be completed with each of the other items. Removing item six, however, slightly reduced the Cronbach’s alpha level of the scale therefore the item was included in the analysis. Item one, “the lab assignment…was complex”, correlated highly with each of the other items with correlations of at least .54. Based on the reliability analysis of the lab
assignment characteristics questionnaire, the data shows that the items factor together to form one lab complexity construct. Therefore, the data from lab assignment characteristics questionnaire will be hereafter referred to as lab complexity rating.

Table 3.1

<table>
<thead>
<tr>
<th>Item 1: Complexity</th>
<th>Item 2: Stressfulness</th>
<th>Item 3: Difficulty</th>
<th>Item 4: Workload</th>
<th>Item 5: Mental Challenge</th>
<th>Item 6: Task Variety</th>
</tr>
</thead>
<tbody>
<tr>
<td>Item 1: Complexity</td>
<td>1.000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Item 2: Stressfulness</td>
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<td>1.000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Item 3: Difficulty</td>
<td>.592</td>
<td>.667</td>
<td>1.000</td>
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<td></td>
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<tr>
<td>Item 4: Workload</td>
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<td>.504</td>
<td>.469</td>
<td>1.000</td>
<td></td>
</tr>
<tr>
<td>Item 5: Mental Challenge</td>
<td>.608</td>
<td>.592</td>
<td>.656</td>
<td>.489</td>
<td>1.000</td>
</tr>
<tr>
<td>Item 6: Task Variety</td>
<td>.541</td>
<td>.288</td>
<td>.345</td>
<td>.545</td>
<td>.437</td>
</tr>
</tbody>
</table>

Previous Lab Assignments

There were 14 lab assignments over the course of the semester so the number could not exceed 14. Based on the course syllabus, assignments 3, 4, 5, 7, 8, 9, and 12 were to be completed in teams. Therefore, it was expected that prior to starting assignment 7 teams would have already worked on three labs as a team. Prior to starting lab assignment 8 they would have worked on four labs as a team. Prior to lab assignment 9 they would have worked on five labs as a team. Participants were observed by the researcher throughout the semester to verify this schedule and determine the number of lab assignments students had worked on previously with their team prior to starting lab assignments 7, 8, and 9. Observations confirmed that the above lab assignments were the only ones worked on as a team.
SMM Measures

Measures of SMM consist of team members’ knowledge in terms of both content and structure (Mohammed et al., 2000). Team and task-related SMM content measures indicate the level of and similarity between team members’ perceptions of team and general task elements. Team and task-related SMM structure measures provide a representation of the underlying composition of team SMM.

Team Assessment Diagnostic Measure

In this study, Team-SMM content was elicited via a questionnaire (e.g. Blickensderfer et al., 1999; Levesque, Wilson, & Wholey, 2001; Rentsch et al., 1998) called the Team Assessment Diagnostic Measure (TADM). The TADM includes each of the five team and general task SMM factors identified by Johnson et al. (2007) including: general task and team knowledge, communication skills, attitude toward teammates and task, team dynamics and interactions, and team resources and working environment. Each team member responded to a series of 15 statements corresponding to the five factors (three statements for each factor) on a five-point scale ranging from strongly disagree to strongly agree. Participants completed the questionnaire individually after each team lab assignment so that no participant was able to see their partners’ individual responses. The three responses for each factor were averaged for each participant to generate one score per factor per participant. Since this study is concerned with the overall TADM score, the five individual factor scores were averaged to generate one overall TADM score per participant.

The TADM mean score outcome variable was the average of the overall TADM scores for all participants within a team. Though this study was mainly concerned with the overall team score with all five factors combined, a TADM mean score could also be obtained for each individual factor separately. This measure represented the level of team member SMM content in terms of the responses to the statements provided. Responses closer to the strongly agree end of the scale indicated positive outlook regarding critical team SMM factors whereas responses closer to the strongly disagree end of the scale indicated negative team outlook. The TADM SD score outcome variable was the proximity of each team member’s TADM mean score to the overall team TADM mean score. This measure represented the similarity of team member SMM content in terms of the responses to the statements provided. The following example is provided for illustrative purposes. Three team members may have responded in a similar manner to each
of the TADM statements which resulted in a low TADM SD and theoretically a greater shared mental model. These responses, however, may have been closer to the strongly disagree end of the scale indicating that, although the mental model was shared, the team members had a negative opinion about their team in terms of the five SMM factors as indicated by a low TADM mean score.

Team-SMM Structure

The Team-SMM Structure outcome variable was measured using a representational technique (Mohammed et al., 2000) that aggregates individual team member ratings regarding the relatedness of six team and general task knowledge factors. These factors are based on Mathieu et al.’s (2000) team-SMM components and include: environment, knowledge, skills, attitudes, dynamics, and resources. Participants were provided with all possible pairing of these components and then asked, as individuals, to rate each pairing on a seven-point scale ranging from ‘totally unrelated’ to ‘highly related’. The individual relatedness ratings were analyzed to determine SMM structure using the Pathfinder program. Pathfinder takes the raw comparison ratings and transforms them into a network structure using multi-dimensional scaling techniques (Schvaneveldt, 1990). Concepts that are highly related to one another are more closely linked within the structure. An index referred to as C (closeness) provided one score representing the SMM based on the relatedness ratings from each team member. The values of C ranged from 0 to 1, with 1 representing perfect similarity (Stout et al., 1999). See Appendix G for the team SMM content and structure instruments.

Team Performance Measures

Team lab assignment scores as well as team quiz scores served as the performance measures for this study. Team lab assignments required teams to apply the information they had read in their lab manual and / or received from the lab instructor to a series of structured tasks. The assignments were graded by the lab instructor based on established grading criteria for a maximum of ten possible points. The scores represented a combination of accuracy and completeness of the lab tasks. Scores on lab assignments 7, 8 and 9 were used as the performance indicators for this study.

The primary researcher along with two MET 1010 lab instructors developed the team quiz for the material covered in labs 7, 8, and 9. The quiz questions were developed based on previous quizzes from labs 7, 8, and 9 that were provided by two of the MET 1010 summer
session lab instructors. The team quiz was submitted to the head instructor and each lab instructor to gain approval as a valid assessment instrument. It was also used in a similar MET 1010 summer study and had high face validity for assessing student knowledge of the lab material. The quiz contained true / false, multiple choice, and short answer questions for a total of 15 points. Team quizzes were graded by each team’s lab instructor based on a standardized answer key. Team quiz scores were converted to a 10 point scale to make statistical and visual comparisons to the lab assignments easier.

Data Collection Procedures

This study used a between groups experimental design with teams assigned to either the treatment condition or the control condition. Teams in the treatment condition received the TKS process intervention while those in the control condition engaged in the individual newspaper article task. Other than administration of the intervention or control task, all teams went through the same procedures and were responsible for completing the same measures and assignments.

The study was introduced to each lab section during the second lab session. Students then received the informed consent letter (Appendix G) and those who choose to participate signed the informed consent form. The primary researcher collected the informed consent forms and advised participants that they could withdraw from the study anytime without penalty. Participants then completed the demographic survey administered through the MET 1010 website. Within each lab section, participants were randomly assigned to teams of three or four members. These same teams remained intact for the duration of the semester though some students dropped the course thereby reducing the number of individuals on that team. In two cases, this left teams with two members.

Participants worked as teams on lab assignments 3, 4, and 5 without receiving either the treatment or the control. Teams typically worked on their lab assignments in class for approximately 60 to 90 minutes. The rationale was to provide students with experience working in their teams before introducing an intervention. Prior to the beginning of lab session 7, teams within each lab were randomly assigned to either the treatment or control condition. One-half of the teams (n = 17) were assigned to the treatment condition and the other half of the teams (n = 17) were assigned to the control condition. Participants and lab instructors were blind as to the nature of the condition that each team was in and the hypothesized outcomes. Teams in the
treatment condition received the TKS intervention immediately preceding lab sessions 7, 8, and 9 for a total of three TKS intervention points. Teams in the control condition were taken to another room to engage in the control task immediately preceding lab sessions 7, 8, and 9 for a total of three administrations.

Immediately following the TKS activity or the control task, teams worked on their lab assignments in class for approximately 60 to 90 minutes. Upon completing and submitting the assignment, teams completed the TADM and SMM Structure measures administered through the MET 1010 website. These measures took approximately 5 minutes in total to complete. The team quiz was administered at the beginning of lab session 10. Participants worked as teams on lab assignment 12 without receiving either the treatment or the control prior to beginning the labs. Like in labs 7, 8, and 9, teams worked on their lab assignments in class for approximately 60 to 90 minutes.

At the end of lab session 12 and upon completion of the final SMM questionnaire, all teams were debriefed regarding the nature of the study and the experimental condition that they were in. The primary researcher answered any remaining questions that teams or individual students had about the study. Table 3.2 provides an overview of the data collection procedures and the corresponding measures for each condition.
Table 3.2
Data collection procedures including tasks and dependent measures for each condition

<table>
<thead>
<tr>
<th>Lab</th>
<th>Condition</th>
<th>Tasks</th>
<th>Dependent Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td></td>
<td>- Study overview (3min)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Informed consent (3min)</td>
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<tr>
<td></td>
<td></td>
<td>- Demographic instrument (5min)</td>
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Random assignment of students to teams

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td>3, 4, 5</td>
<td>n = 34 teams</td>
<td>Team Lab Assignments</td>
</tr>
</tbody>
</table>

Random assignment of teams to treatment and control

<table>
<thead>
<tr>
<th>Treatment</th>
<th>n= 17 teams</th>
<th>“TKS” (15min)</th>
<th>Lab assignment score</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Team Lab Assignment</td>
<td>TADM</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SMM instrument (10min)</td>
<td>SMM Structure</td>
</tr>
</tbody>
</table>

Control

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<tr>
<th>n= 17 teams</th>
<th>Control (15min)</th>
<th>Lab assignment score</th>
</tr>
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<td>SMM Structure</td>
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Treatment

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<tr>
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Control

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<tr>
<td></td>
<td>SMM instrument (10min)</td>
<td>SMM Structure</td>
</tr>
</tbody>
</table>

10 | n = 34 teams | Team quiz (15 min) | Team quiz score |

12 |   | Team Lab Assignment | Lab assignment score |
Data Analysis

After the data was collected, it was first necessary to aggregate the responses to the elicitation measures to generate SMM content and structure scores. For SMM content, this involved generating a mean and standard deviation statistic for each team at each measurement point. This was carried out in Microsoft Excel. For SMM structure, the individual ratings of team factors were entered into the Pathfinder program. This program used an algorithm to generate one structure score for each team at each measurement point.

Once the SMM scores were generated, the second phase of data analysis involved assessing the differences between the treatment and control group on SMM scores and performance scores for each lab assignments 7, 8, and 9. Interaction effects were also analyzed. Each specific analysis technique is discussed in the context of the research questions and hypotheses below.

Research Questions, Hypotheses, and Analysis Techniques

The general research question for this study was: what is the effect of a TKS intervention on SMM and team performance in an undergraduate meteorology laboratory course? In order to answer the general question, there were four supporting research questions organized around two major themes.

Theme 1: Effect of the TKS intervention on SMM

Supporting research question 1.1. What is the effect of the TKS intervention on team and task-related SMM for specific meteorology lab assignments?

Theoretical hypothesis 1.1.1. The level of team and task-related SMM will be greater for teams that receive the TKS intervention than for teams that do not.

Theoretical hypothesis 1.1.2. The similarity of team and task-related SMM will be greater for teams that receive the TKS intervention than for teams that do not.

Theoretical hypothesis 1.1.3. The structure of team and task-related SMM will be more similar for teams that receive the TKS intervention than for teams that do not.

Operational hypothesis 1.1.1. For specific team lab assignments, the TADM mean score will be significantly greater for teams that receive the TKS intervention as compared to teams that do not receive the intervention.
**Operational 1.1.2.** For specific team lab assignments, the TADM standard deviation score will be significantly lower for teams that receive the TKS intervention as compared to teams that do not receive the intervention.

**Operational 1.1.3.** For specific team lab assignments, Team-SMM Structure score calculated by the Pathfinder program will be significantly greater for teams that receive the TKS intervention as compared to teams that do not receive the intervention.

**Data analysis 1.1.1.** One-way Multivariate Analysis of Variance (MANOVA) was carried out for each SMM measurement point corresponding to lab assignments 7, 8, and 9. The independent variable (IV), “intervention type” was made up of two levels: TKS intervention and control. The combined dependent variable (DV) comprised: TADM mean score, TADM standard deviation score, and Team-SMM Structure score. One-way Analysis of Variance (ANOVA) was conducted for each individual DV including TADM mean score, TADM standard deviation score, and Team-SMM structure score at each measurement point (labs 7, 8, and 9).

**Supporting research question 1.2.** Does the effect of the TKS intervention on team and task-related SMM vary depending on the number of previous team lab assignments?

**Theoretical hypothesis 1.2.1.** The amount of influence of the TKS intervention on TADM mean score will depend on the number of previous team lab assignments.

**Theoretical hypothesis 1.2.2.** The amount of influence of the TKS intervention on TADM standard deviation score variance will depend on the number of previous team lab assignments.

**Theoretical hypothesis 1.2.3.** The amount of influence of the TKS intervention on Team-SMM Structure score will depend on the number of previous team lab assignments.

**Operational hypothesis 1.2.1.** On TADM mean score, the interaction effect between the TKS intervention and the number of previous team lab assignments will be significant.
Operational hypothesis 1.2.2. On TADM standard deviation score, the interaction effect between the TKS intervention and the number of previous team lab assignments will be significant.

Operational hypothesis 1.2.3. On Team-SMM Structure score, the interaction effect between the TKS intervention and the number of previous team lab assignments will be significant.

Data analysis. Two-way MANOVA was carried out to determine the interaction effect of “intervention type” (TKS and control) and “previous lab assignments” on the combined DV of SMM degree score mean, SMM degree standard deviation, and SMM structure score. “Previous lab assignments” was a continuous variable with responses ranging from three through five. That is, prior to starting assignment 7 teams had already worked on three labs as a team. Prior to starting lab assignment 8 they had worked on four labs as a team. Prior to lab assignment 9 they had worked on five labs as a team. The goal was to determine whether the effect of the intervention on team SMM varied depending on the number of times the team had worked together on assignments.

Theme 2: Effect of the TKS Intervention on Team Performance in the MET 1010 Lab

Supporting research question 2.1. What is the effect of the TKS intervention on team lab assignment and quiz performance?

Theoretical hypothesis 2.1.1. Team performance scores on specific lab assignments will be greater for teams that receive the TKS intervention.

Theoretical hypothesis 2.1.2. Team quiz performance scores on will be greater for teams that receive the TKS intervention.

Operational hypothesis 2.1.1. On specific meteorology team lab assignments, teams that receive the TKS intervention will score significantly higher than teams that do not receive the intervention.

Operational hypothesis 2.1.2. On the meteorology team quiz, teams that receive the TKS intervention will score significantly higher than teams that do not receive the intervention.
Data analysis. One-way MANOVA was carried out to determine the effect of the TKS intervention on lab assignment performance and team quiz performance. The IV was “intervention type” (TKS and control) and the combined DV was team lab assignment score for lab assignments 7, 8, and 9 and team quiz score. The advantage of using the MANOVA procedure was that it allowed the researcher to get a holistic picture of team performance while reducing the within groups error resulting from two separate one-way ANOVAs (Mertler & Vannatta, 2002).

Follow-up one-way ANOVAs were carried out for team scores on lab assignments 7, 8, and 9 and the team quiz score. The IV was “intervention type” (TKS and control). The DV was team lab assignment and quiz score from zero to 10. One-way ANOVA was carried out for the team quiz score.

Supporting research question 2.2. Does the effect of the TKS intervention on team lab assignment performance vary depending on lab complexity?

Theoretical hypothesis 2.2.1. The influence of the TKS intervention on team lab assignment scores will vary depending on perceived lab complexity.

Operational hypothesis 2.2.1. On team lab assignment scores, the interaction effect between the TKS intervention and lab complexity will be significant.

Data analysis. Two-way ANOVA was carried out to examine the interaction effect between the treatment and perceived lab complexity on lab assignment score. The IVs were “intervention type” (TKS and control) and “lab complexity” (a discrete value assigned to each lab based on student complexity ratings). The DV was the pooled team lab assignment scores from zero to 10. The goal was to determine whether the effect of the intervention on team lab assignment score varied depending on the perceived lab assignment complexity.
The next chapter presents the results of the study relative to the research questions and hypotheses.
CHAPTER IV: RESULTS

In this study, the effects of an SMM based intervention on team mental model similarity and student team performance were examined in an undergraduate meteorology laboratory course. The intervention targeted team and task-related knowledge sharing (TKS) processes through promoting team reflection, communication, and improvement planning thereby enhancing SMM and ultimately improving team performance on meteorology lab assignments. The TKS intervention was based on previously established SMM based interventions as well as five SMM factors including: general task and team knowledge, communication skills, attitude toward teammates and task, team dynamics and interactions, and team resources and working environment.

The general research question was: *what is the effect of a TKS intervention on team and task-related SMM and team performance in an undergraduate meteorology laboratory course?* In order to answer this question, an experiment was conducted whereby student teams in MET 1010 lab were randomly assigned to either a treatment or control condition. Prior to working on team lab assignments, teams in the treatment condition received the TKS intervention while teams in the control condition engaged in a non-SMM activity. The control activity covered the same time as the team intervention but did not require any team activity related to the TKS intervention.

This chapter first presents the descriptive statistics for the dependent variables in the control and treatment conditions. The inferential statistics corresponding to the two major research themes of the study are then presented in sections that follow. The first section deals with the effect of the TKS intervention on Team-SMM content and structure. Team-SMM content is broken down into level and similarity which are labeled as TADM mean score and TADM SD score respectively. Team-SMM structure is represented by the C (closeness) score as calculated by the Pathfinder program. SMM content and structure were assessed within the context of teams working on meteorology lab assignments. The first section also explores an interaction in terms of whether the effect of the TKS intervention on Team-SMM varied depending on the number of team lab assignments the team has worked on previously.

The second section of this chapter deals with the effect of the TKS intervention on team performance on team lab assignments and a team quiz within the MET 1010 lab. The second section also explores an interaction in terms of whether the effect of the TKS intervention on
team performance varied depending on perceived lab assignment complexity. Team-SMM content, structure, and team performance were assessed within the context of teams working on meteorology lab assignments 7, 8, and 9 in which the intervention was applied.

Descriptive Statistics

The descriptive statistics including means, standard deviations, and sample size for the dependent variables are presented in Table 4.1. The specific dependent variables were: Team-SMM content (TADM mean and SD scores), Team-SMM Structure score, and team performance (lab assignment 7, 8, and 9 scores and team quiz score). Based on an examination of the means, it appears that the TKS intervention generally had a positive effect on Team-SMM and team performance. There were exceptions to this such as the higher lab assignment 9 score for the control group. The statistical significance of these mean differences for the two major themes was examined through inferential statistical tests.

<table>
<thead>
<tr>
<th>Table 4.1</th>
<th>Control and treatment group descriptive statistics for each dependent variable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group</td>
<td>Control</td>
</tr>
<tr>
<td></td>
<td>M</td>
</tr>
<tr>
<td>Outcome Measure</td>
<td></td>
</tr>
<tr>
<td>TADM mean</td>
<td></td>
</tr>
<tr>
<td>Lab Assignment 7</td>
<td>4.03</td>
</tr>
<tr>
<td>Lab Assignment 8</td>
<td>4.03</td>
</tr>
<tr>
<td>Lab Assignment 9</td>
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</tr>
<tr>
<td>Totals</td>
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<tr>
<td>TADM SD</td>
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</tr>
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<td>Lab Assignment 7</td>
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</tr>
<tr>
<td>Lab Assignment 8</td>
<td>.44</td>
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<td>Lab Assignment 9</td>
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<tr>
<td>Totals</td>
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<td>Structure</td>
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</tr>
<tr>
<td>Lab Assignment 8</td>
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</tr>
<tr>
<td>Lab Assignment 9</td>
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</tr>
<tr>
<td>Totals</td>
<td>.49</td>
</tr>
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</table>
Table 4.1 continued

<table>
<thead>
<tr>
<th>Outcome Measure</th>
<th>Control</th>
<th>Treatment</th>
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</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
<td>n</td>
</tr>
<tr>
<td>Assignment Score g.h.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lab Assignment 7</td>
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<td>.95</td>
<td>17</td>
</tr>
<tr>
<td>Lab Assignment 8</td>
<td>9.15</td>
<td>.71</td>
<td>17</td>
</tr>
<tr>
<td>Lab Assignment 9</td>
<td>9.57</td>
<td>.43</td>
<td>17</td>
</tr>
</tbody>
</table>

Team Quiz Score i.j. | 8.64 | .60  | 17 | 8.95 | .64 | 17 | 8.80 | .62 | 34 |

Notes.

a. Treatment and control group TADM mean score summary statistics for each lab assignment
b. The range of possible TADM mean scores was from 1 to 5
c. Treatment and control group TADM SD summary statistics for each lab assignment
d. The range of possible TADM SD scores was from .00 to 1.00
e. Treatment and control group Team-SMM structure summary statistics for each lab assignment
f. The range of possible Team-SMM structure scores was from .00 to 1.00
g. Treatment and control group lab assignment score summary statistics for each lab assignment
h. The range of possible scores on lab assignments was from 0 to 10
i. Treatment and control group team quiz score summary statistics
j. The range of possible scores on the team quiz was from 0 to 10

Theme 1: Effect of the TKS Intervention on Team-SMM

The two supporting research questions relative to the Team-SMM theme were: What is the effect of the TKS intervention on team and task-related SMM for specific meteorology lab assignments? and Does the effect of the TKS intervention on team and task-related SMM vary depending on the number of previous team lab assignments? The operational hypotheses along with the corresponding results of the statistical tests are presented below. The main effect results are presented first followed by the interaction results.
**Operational Hypothesis 1.1.1**

For specific team lab assignments, the TADM mean score will be significantly greater for teams that receive the TKS intervention as compared to teams that do not receive the intervention.

**Operational Hypothesis 1.1.2**

For specific team lab assignments, the TADM standard deviation will be significantly lower for teams that receive the TKS intervention as compared to teams that do not receive the intervention.

**Operational Hypothesis 1.1.3**

For specific team lab assignments, Team-SMM Structure score calculated by the Pathfinder program will be significantly greater for teams that receive the TKS intervention as compared to teams that do not receive the intervention.

The stem and leaf plots and the box plots revealed several outliers in the treatment group for lab assignment 7, 8, and 9 TADM mean scores as well as for lab assignment 7 and 9 TADM SD scores. Also, four outliers were identified in the control group for Team-SMM structure scores across all three lab assignments. The outliers were indentified as extreme cases by SPSS in that they were at least 1.5 SD above or below the mean and in most cases 2 SD above or below the mean. Based on the histograms and normality plots with tests, these outliers appeared to be skewing the data in a positive direction in some instances and a negative direction in others. The decision was made to run the analyses and present the results with the outliers included then run the same analyses and present the results with the outliers removed.

*Theme 1 Main Effect Results*

Three One-way MANOVAs were carried out for each SMM measurement point corresponding to lab assignments 7, 8, and 9. The IV, “intervention type” is made up of two levels: TKS intervention and control. The combined DV comprises: TADM mean score, TADM SD score, and Team-SMM structure score for each measurement point (i.e., lab assignment).
Lab Assignment 7: Outliers Included

For lab assignment 7, Box’s test for equality of covariance was significant indicating a violation of the homoscedasticity assumption. Therefore, a more robust multivariate test statistic, Pillai’s Trace, was selected to interpret the results. MANOVA results indicate that the TKS intervention significantly affected the combined DV of lab assignment 7 TADM mean score, TADM SD score, and Team-SMM Structure score (Pillai’s Trace = .265, $F(3,30)=3.61, p < .05$, partial $\eta^2 = .265$). Individual One-way ANOVAs were run for each DV and results are presented below.

ANOVA results indicate there was no significant difference between the TKS treatment group and the control group on the TADM mean score $F(1,32)= 0.02, p = 0.90$, partial $\eta^2 = .001$. These results fail to support the hypothesis that for lab assignment 7 the TADM mean score will be significantly greater for teams that receive the TKS intervention as compared to teams that do not receive the intervention.

ANOVA results indicate there was a significant difference between the TKS treatment group and the control group on TADM SD score $F(1,32) = 9.42, p < .05$, partial $\eta^2 = .227$. These results are consistent with the hypothesis; the lab assignment 7 TADM standard deviation score was significantly lower for the treatment group when compared to the control group.

ANOVA results indicate there was no significant difference between the TKS treatment group and the control group on Team-SMM Structure score $F(1,32) = 1.64, p = .21$, partial $\eta^2 = .049$. These results fail to support the hypothesis that for specific team lab assignments Team-SMM Structure similarity scores will be significantly greater for teams that receive the TKS intervention as compared to teams that do not receive the intervention.

Table 4.2 presents the Means and SDs and for the control and treatment group TADM mean scores, TADM SD scores, and Team-SMM Structure scores for lab assignment 7 with outliers included in the analysis.
Table 4.2
Lab assignment 7 SMM outcome summary statistics with outliers included

<table>
<thead>
<tr>
<th>SMM Measure</th>
<th>TADM mean</th>
<th>TADM SD</th>
<th>Team-SMM Structure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group</td>
<td>Mean</td>
<td>SD</td>
<td>n</td>
</tr>
<tr>
<td>Control</td>
<td>4.03</td>
<td>.41</td>
<td>17</td>
</tr>
<tr>
<td>Treatment</td>
<td>4.01</td>
<td>.40</td>
<td>17</td>
</tr>
</tbody>
</table>

* Significant difference between control and treatment, $p < .05$

**Lab Assignment 7: Outliers Removed**

For lab assignment 7, Box’s test for equality of covariance was significant indicating a violation of the homoscedasticity assumption. Therefore, a more robust multivariate test statistic, Pillai’s Trace, was selected to interpret the results. MANOVA results with outliers removed were generally consistent with those when outliers were included, indicating that the TKS intervention significantly affected the combined DV of lab assignment 7 TADM mean score, TADM SD score, and Team-SMM Structure score (Pillai’s Trace = .373, $F(3,24) = 4.77, p < .05$, partial $\eta^2 = .373$). Note that with outliers removed the effect size was slightly larger.

Table 4.3 presents the Means and SDs and for the control and treatment group TADM mean scores, TADM SD scores, and Team-SMM structure scores for lab assignment 7 with outliers removed from the analysis.

Table 4.3
Lab assignment 7 SMM outcome summary statistics with outliers removed

<table>
<thead>
<tr>
<th>SMM Measure</th>
<th>TADM mean</th>
<th>TADM SD</th>
<th>Team-SMM Structure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group</td>
<td>Mean</td>
<td>SD</td>
<td>n</td>
</tr>
<tr>
<td>Control</td>
<td>4.03</td>
<td>.41</td>
<td>17</td>
</tr>
<tr>
<td>Treatment</td>
<td>3.96</td>
<td>.14</td>
<td>11</td>
</tr>
</tbody>
</table>

* Significant difference between control and treatment, $p < .05$
Lab Assignment 8: Outliers Included

For lab assignment 8, Box’s test for equality of covariance was non-significant indicating that the homoscedasticity assumption was supported thus rendering Wilk’s Lambda an appropriate multivariate statistic. MANOVA results indicated that the TKS intervention significantly affected the combined DV of lab assignment 8 TADM mean score, TADM SD score, and Team-SMM Structure score (Wilks’ $\Lambda = .716$, $F(3,29)=3.83$, $p < .05$, partial $\eta^2 = .284$). Individual one-way ANOVAs were run for each DV as presented below.

ANOVA results indicate there was no significant difference between the TKS treatment group and the control group on the TADM mean score $F(1,31) = .002$, $p = .96$, partial $\eta^2 = .000$. These results fail to support the hypothesis that for lab assignment 8 the TADM mean score will be significantly greater for teams that receive the TKS intervention as compared to teams that do not receive the intervention.

ANOVA results indicate there was a significant difference between the TKS treatment group and the control group on TADM SD score $F(1,31) = 7.04$, $p < .05$, partial $\eta^2 = .185$. These results are consistent with the hypothesis; lab assignment 8 TADM SD score was significantly lower for the treatment group when compared to the control group.

ANOVA results indicate there was a significant difference between the TKS treatment group and the control group on Team-SMM Structure scores $F(1,31) = 4.54$, $p < .05$, partial $\eta^2 = .128$. These results are consistent with the hypothesis that for specific team lab assignments, Team-SMM Structure similarity score will be significantly greater for teams that receive the TKS intervention as compared to teams that do not receive the intervention.

Table 4.4 presents the Means and SDs and for the control and treatment group TADM mean scores, TADM SD scores, and Team-SMM Structure scores for lab assignment 8 with outliers included in the analysis.
Table 4.4
Lab assignment 8 SMM outcome summary statistics with outliers included

<table>
<thead>
<tr>
<th>SMM Measure</th>
<th>TADM mean</th>
<th>TADM SD</th>
<th>Team SMM-Structure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group</td>
<td>Mean</td>
<td>SD</td>
<td>n</td>
</tr>
<tr>
<td>Control</td>
<td>4.03</td>
<td>.38</td>
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</tr>
<tr>
<td>Treatment</td>
<td>4.03</td>
<td>.40</td>
<td>17</td>
</tr>
</tbody>
</table>

* Significant difference between control and treatment, $p < .05$

**Lab Assignment 8: Outliers Removed**

For lab assignment 8, Box’s test for equality of covariance was non-significant indicating that the homoscedasticity assumption was supported thus rendering Wilk’s Lambda an appropriate multivariate statistic. MANOVA results with outliers removed were generally consistent with those when outliers were included indicating that the TKS intervention significantly affects the combined DV of lab assignment 8 TADM mean score, TADM SD score, and Team-SMM Structure score (Wilks’ $\Lambda = .584$, $F(3,25)=5.93$, $p < .05$, partial $\eta^2 = .416$).

Note that with outliers removed the effect size was slightly larger.

Table 4.5 presents the Means and SDs and for the control and treatment group TADM mean scores, TADM SD scores, and Team-SMM Structure scores for lab assignment 8 with outliers removed from the analysis.

Table 4.5
Lab assignment 8 SMM outcome summary statistics with outliers removed

<table>
<thead>
<tr>
<th>SMM Measure</th>
<th>TADM mean</th>
<th>TADM SD</th>
<th>Team SMM-Structure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group</td>
<td>Mean</td>
<td>SD</td>
<td>n</td>
</tr>
<tr>
<td>Control</td>
<td>4.06</td>
<td>.35</td>
<td>14</td>
</tr>
<tr>
<td>Treatment</td>
<td>3.92</td>
<td>.24</td>
<td>15</td>
</tr>
</tbody>
</table>

* Significant difference between control and treatment, $p < .05$
**Lab Assignment 9: Outliers Included**

For lab assignment 9, Box’s test for equality of covariance was non-significant indicating that the homoscedasticity assumption was supported thus rendering Wilk’s Lambda an appropriate multivariate statistic. MANOVA results indicate that there was no significant difference between the TKS intervention group and the control group on the combined DV of lab assignment 9 TADM mean score, TADM SD score, and SMM structure score (Wilks’ $\Lambda = .934$, $F(3,30)= 0.71$, $p = .55$, partial $\eta^2 = .066$).

Table 4.6 presents the Means and SDs and for the control and treatment group TADM mean scores, TADM SD scores, and Team-SMM Structure scores for lab assignment 9 with outliers included in the analysis.

Table 4.6
Lab assignment 9 outcome summary statistics with outliers included

<table>
<thead>
<tr>
<th>SMM Measure</th>
<th>TADM mean</th>
<th>TADM SD</th>
<th>Team SMM-Structure</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Group</strong></td>
<td>Mean SD n</td>
<td>Mean SD n</td>
<td>Mean SD n</td>
</tr>
<tr>
<td>Control</td>
<td>4.01 .34 17</td>
<td>.31 .22 17</td>
<td>.50 .17 17</td>
</tr>
<tr>
<td>Treatment</td>
<td>3.98 .30 17</td>
<td>.30 .27 17</td>
<td>.60 .22 17</td>
</tr>
</tbody>
</table>

**Lab Assignment 9: Outliers Removed**

For lab assignment 9, Box’s test for equality of covariance was non-significant indicating that the homoscedasticity assumption was supported thus rendering Wilk’s Lambda an appropriate multivariate statistic. MANOVA results with outliers removed were generally consistent with those when outliers were included indicating that there is no significant difference between the TKS intervention group and the control group on the combined DV of lab assignment 9 TADM mean score, TADM SD score, and Team-SMM structure score (Wilks’ $\Lambda = .822$, $F(3,26)=1.88$, $p = .16$, partial $\eta^2 = .178$). Though the effect size was slightly larger than with outliers included, the test was still non-significant.
Between-subjects effects test results indicate there was a significant difference between the TKS treatment group and the control group on Team-SMM structure score $F(1,32) = 5.11$, $p < .05$, partial $\eta^2 = .154$. These results are consistent with the hypothesis that for lab assignment 9, Team-SMM Structure similarity score will be significantly greater for teams that receive the TKS intervention as compared to teams that do not receive the intervention.

Table 4.7 presents the Means and SDs and for the control and treatment group TADM mean scores, TADM SD scores, and Team-SMM Structure scores for lab assignment 9 with outliers removed from the analysis.

<table>
<thead>
<tr>
<th>SMM Measure</th>
<th>TADM mean</th>
<th>TADM SD</th>
<th>Team SMM-Structure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group</td>
<td>Mean</td>
<td>SD</td>
<td>$n$</td>
</tr>
<tr>
<td>Control</td>
<td>4.00</td>
<td>.35</td>
<td>16</td>
</tr>
<tr>
<td>Treatment</td>
<td>3.95</td>
<td>.19</td>
<td>14</td>
</tr>
</tbody>
</table>

* Significant difference between control and treatment, $p < .05$

In sum, there were significant differences between the TKS treatment and control group on the following SMM related dependent variables: lab assignment 7 TADM SD score, lab assignment 8 TADM SD score and lab assignment 8 Team-SMM Structure score. The direction of these differences was consistent with the hypotheses. Removing the indentified outliers generally increased the effect sizes of the mean comparisons but did not substantially change the results in terms of finding significant differences between the treatment and control. The one exception to this was lab assignment 9 Team-SMM Structure score. With outliers included there was no significant difference between the treatment and control group. Removing the outliers and re-running the analysis resulted in a significant difference with the treatment group scoring significantly higher than the control group which is consistent with the hypothesis.
Figures 4.1, 4.2, and 4.3 depict the control and treatment group marginal means for TADM mean scores, TADM SD scores, and Team-SMM Structure scores for lab assignments 7, 8, and 9 with outliers included in the analysis.

**Figure 4.1.** Marginal means for lab assignment 7, 8, and 9 TADM mean scores

**Figure 4.2.** Marginal means for lab assignment 7, 8, and 9 TADM SD scores
Results for the SMM and number of previous lab assignments interaction hypotheses are presented next.

**Operational Hypothesis 1.2.1**

On TADM mean score, the interaction effect between the TKS intervention and the number of previous team lab assignments will be significant.

**Operational Hypothesis 1.2.2**

On TADM SD score, the interaction effect between the TKS intervention and the number of previous team lab assignments will be significant.

**Operational Hypothesis 1.2.3**

On Team-SMM Structure score, the interaction effect between the TKS intervention and the number of previous team lab assignments will be significant.

**Theme 1 Interaction Effect Results**

Two-way MANOVA was carried out to determine the effect of “intervention type” (TKS and control) and “previous lab assignments” on the combined DV of TADM mean score,
TADM SD score, and Team-SMM Structure score. “Previous lab assignments” was an ordinal variable with responses ranging from three through five. That is, prior to starting assignment 7 teams had already worked on three labs as a team. Prior to starting lab assignment 8 they had worked on four labs as a team. Prior to lab assignment 9 they had worked on five labs as a team. The goal of the interaction hypothesis was to determine whether the effect of the intervention on team SMM varied depending on the number of times the team has worked together on assignments.

Box’s test for equality of covariance was non-significant indicating that the homoscedasticity assumption was supported thus rendering Wilk’s Lambda an appropriate multivariate statistic. Two-way MANOVA results reveal there was no significant interaction effect between intervention type and previous lab assignments on the combined DV of TADM mean score, TADM SD score, and Team-SMM Structure score (Wilks’ \( \Lambda = .952, F(6,186)= 0.77, p = .59, \) partial \( \eta^2 = .024 \)).

One-way ANOVA was conducted to determine whether there were significant differences between the lab assignments 7, 8, and 9 on the outcomes of TADM mean score, TADM SD score, and Team-SMM structure score. In other words, are there any systematic changes in SMM outcomes as student teams work together over a three lab time interval? Results show there were no significant differences between any of the lab assignments for TADM mean score \( F(2,98) =.106, p = .899 \), TADM SD score \( F(2,98) =.282, p = .755 \), and Team-SMM structure score \( F(2,98) =.142, p = .87 \). There was no main effect of time (number of previous lab assignments completed as a team) on SMM outcomes. The next section presents the results for the second theme regarding the effect of the TKS intervention on team performance.

Theme 2: Effect of the TKS Intervention on Team Performance

The two supporting research questions relative to the team performance theme were: What is the effect of the TKS intervention on team lab assignment and quiz performance? and Does the effect of the TKS intervention on team lab assignment performance vary depending on lab complexity? The operational hypotheses along with the corresponding results of the statistical tests are presented below.
**Operational Hypothesis 2.1.1**

On specific meteorology team lab assignments, teams that receive the TKS intervention will score significantly higher than teams that do not receive the intervention.

---

**Operational Hypothesis 2.1.2**

On the meteorology team quiz, teams that receive the TKS intervention will score significantly higher than teams that do not receive the intervention.

The stem and leaf plots and the box plots revealed two outliers in the treatment group and two outliers in the control group for lab assignment 9 performance scores. All four outliers were at least 2 SD below the mean. ANOVA results with outliers included and with outliers excluded are presented for lab assignment 9 scores. There was one outlier in the treatment group for the team quiz score. This outlier was at least 2 SD below the mean quiz score. For this reason, the one-way ANOVA examining the differences between the treatment group and the control group on the team quiz score was run both with the outlier included and with the outlier excluded.

Upon examining histograms and normality plots with tests, it was determined that the performance scores for the lab assignments were negatively skewed. Square root and logarithmic transformation procedures (Mertler & Vannatta, 2002) did not substantially reduce the skew of the distribution. It appears that a ceiling effect was influencing the distribution of team lab assignment scores where teams often received perfect or near perfect scores. The frequency distributions for team lab assignment treatment and control group scores including all three lab assignments are depicted in Figure 4.4. In light of this skewness and low sample size, a Mann-Whitney *U* non-parametric test was carried out in addition to the individual ANOVAs to examine control and treatment group differences for each lab assignment under study. Mann-Whitney *U* results are presented in addition to its parametric equivalent of independent samples *t*-test.
Figure 4.4. Frequency distributions for team lab assignment scores on lab assignments 7, 8, and 9 combined

The distribution of scores on the team quiz were more sporadic which was likely due to the low sample size (n = 17) in each group as depicted in Figure 4.5.

Figure 4.5. Control and treatment group frequency distributions for team quiz scores
When the control and treatment groups were combined to form a larger sample (n = 34), the normality plots with tests reveal that distribution of scores more closely approximated normal as depicted in Figure 4.6.

![Figure 4.6. Frequency distributions for the entire sample team quiz scores](image)

**Theme 2 Main Effect Results**

One-way MANOVA was carried out to determine the effect of the TKS intervention on team lab assignment performance and team quiz performance. The IV is “intervention type” (i.e., TKS and control) and the combined DV is team lab assignment score for lab assignments 7, 8, and 9 and team quiz score.

Box’s test for equality of covariance was non-significant indicating that the homoscedasticity assumption is supported thus rendering Wilk’s Lambda an appropriate multivariate statistic. MANOVA results indicate that the TKS intervention significantly affected the combined DV of lab assignment 7, 8, and 9 scores and the team quiz score (Wilks’ Λ = .583, $F(4,29)=5.18, p < .05$, partial $\eta^2 = .417$). The direction of this effect was consistent with expectations; the control group overall mean performance score was 8.93 while the treatment
group overall mean performance score was 9.18. Individual one-way ANOVAs were run for each DV with results presented below.

ANOVA results for lab assignment 7 scores indicate there was no significant difference between the TKS treatment group and the control group on the team assignment score $F(1,32) = 2.97, p < .05$, partial $\eta^2 = .085$. This result fails to support the hypothesis; lab 7 assignment scores were not significantly higher for the treatment group when compared to the control group.

ANOVA results for lab assignment 8 scores indicate there was a significant difference between the TKS treatment group and the control group on the team assignment score $F(1,32) = 5.75, p < .05$, partial $\eta^2 = .152$. This result is consistent with the hypothesis; lab 8 assignment scores were significantly higher for the treatment group when compared to the control group.

ANOVA results for lab assignment 9 scores indicate there was a significant difference between the TKS treatment group and the control group on the team assignment score $F(1,32) = 4.52, p < .05$, partial $\eta^2 = .124$. This result is in contrast to the hypothesis; lab 9 assignment scores were significantly higher for the control group when compared to the treatment group. Removing the outliers from the analysis did not substantially change the result though the differences were enhanced as indicated by the larger $F$ statistic, smaller $p$ value, and larger partial Eta squared value $F(1,32) = 7.45, p < .05$, partial $\eta^2 = .210$.

ANOVA results for the team quiz score with the outlier included indicate there was no significant difference between the TKS treatment and the control group on team quiz performance scores $F(1,32) = 2.06, p = .16$, partial $\eta^2 = .060$. This result fails to support the hypothesis; teams in the TKS intervention condition did not score significantly higher on the team quiz than teams in the control condition.

The one outlier was removed and the ANOVA was re-run. Results reveal that with the outlier removed, there was a significant difference between the TKS treatment and the control group on team quiz performance scores $F(1,31) = 4.45, p < .05$, partial $\eta^2 = .125$. This result supports the hypothesis; teams in the TKS intervention condition scored significantly higher on the team quiz than teams in the control condition. Summarized in Table 4.8 and depicted in Figure 4.7 are the means for team performance scores with the team quiz score outlier removed.
Table 4.8
Team performance outcome summary statistics

<table>
<thead>
<tr>
<th>Team Performance Measure</th>
<th>Lab Assignment 7</th>
<th>Lab Assignment 8</th>
<th>Lab Assignment 9</th>
<th>Team Quiz</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group</td>
<td>Mean</td>
<td>SD</td>
<td>n</td>
<td>Mean*</td>
</tr>
<tr>
<td>Control</td>
<td>8.92</td>
<td>.95</td>
<td>17</td>
<td>9.16</td>
</tr>
<tr>
<td>Treatment</td>
<td>9.38</td>
<td>.55</td>
<td>17</td>
<td>9.64</td>
</tr>
</tbody>
</table>

*Significant difference between control and treatment, \( p < .05 \)

Figure 4.7. Team performance scores on lab assignments 7, 8, and 9 and the team quiz

Given the negative skew of the lab assignment performance scores and the somewhat low sample size, a Mann-Whitney \( U \) non-parametric test was conducted to evaluate the hypothesis that for specific lab assignments, teams that receive the TKS intervention will score significantly higher than teams that do not receive the intervention. Summary statistics for lab assignment score ranks are presented in Table 4.9. Test results revealed no significant difference between the control and treatment group for lab assignment 7 score (Mann-Whitney \( U = 106.50, p = .18 \), two-tailed). There was a significant difference between the control and treatment group for lab assignment 8 score (Mann-Whitney \( U = 84.50, p < .05 \), two-tailed). Results reveal there was no
significant difference between the control and treatment group for lab assignment 9 score (Mann-Whitney $U = 90.00, p = .06$, two tailed).

The results for the Mann-Whitney $U$ non-parametric test are consistent with those of the ANOVA for lab assignments 7 and 8. Inconsistent with ANOVA results for lab assignment 9, the results of the non-parametric were non-significant. Mann-Whitney $U$ provides a more conservative estimate than a t-test or ANOVA when an assumption such as normality is violated so the lack of significance for lab assignment 9 is therefore not surprising.

Table 4.9
Team lab assignment performance ranks

<table>
<thead>
<tr>
<th>Group</th>
<th>Lab Assignment 7</th>
<th>Lab Assignment 8</th>
<th>Lab Assignment 9</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean Rank</td>
<td>Sum of Ranks</td>
<td>$n$</td>
</tr>
<tr>
<td>Control</td>
<td>19.74</td>
<td>335.50</td>
<td>17</td>
</tr>
<tr>
<td>Treatment</td>
<td>15.26</td>
<td>259.50</td>
<td>17</td>
</tr>
</tbody>
</table>

* Significant difference between control and treatment, $p < .05$ two-tailed

Note. Value of 1 assigned to the highest score so that lower ranks correspond to higher scores

In sum, lab assignment 7 score mean was higher for the treatment group as compared to the control group though this difference was not significant. Lab assignment 8 score mean was significantly higher for the TKS treatment group as compared to the control group which supports the operational hypothesis. Lab assignment 9 score mean was significantly higher for the control group as compared to the treatment group which is in opposition to the operational hypothesis. The Mann-Whitney $U$ test result for lab assignment was non-significant but only by a slight margin. The team quiz score mean was higher for the treatment group as compared to the control group which is consistent with the operational hypothesis.

To determine if the inversion of scores on lab assignment 9 score was an anomaly, a one-way ANOVA was run comparing the TKS treatment and control groups’ lab assignment 12 scores. Lab assignment 12 is the most immediate team lab assignment following lab assignment 9 since labs 10 and 11 are completed by students as individuals rather than in teams.
ANOVA results for lab assignment 12 scores indicate there was no significant difference between the TKS treatment group and the control group on the team assignment score $F(1,32) = .96, p = .34$, partial $\eta^2 = .029$. Though this result fails to support the hypothesis, the treatment group score was higher than the control group score. This result was consistent with the pattern for lab assignment 7 and 8 scores and the team quiz but was inconsistent with lab assignment 9 scores.

Means and standard deviations for lab assignment 12 are summarized in Table 4.10. The pattern of all mean performance scores is depicted in Figure 4.8.

Table 4.10
Lab assignment 12 score summary statistics

<table>
<thead>
<tr>
<th>Team Performance Measure</th>
<th>Lab Assignment 12</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group</td>
<td>Mean</td>
</tr>
<tr>
<td>Control</td>
<td>9.15</td>
</tr>
<tr>
<td>Treatment</td>
<td>9.40</td>
</tr>
</tbody>
</table>

![Marginal Means](image)

*Figure 4.8. Team performance scores with lab assignment 12 included*

To determine the overall effect of the TKS intervention on team performance a $t$-test was run comparing the control and treatment groups pooled performance scores including lab
assignments 7, 8, 9, and 12 as well as the team quiz. Results reveal a significant difference between the control group and the treatment group on overall performance score: two-sample \( t \) (168) = 2.08, \( p < .05 \). Means and SD for overall performance score are presented in Table 4.11.

<table>
<thead>
<tr>
<th></th>
<th>Overall Performance Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group</td>
<td>Mean*</td>
</tr>
<tr>
<td>Control</td>
<td>9.09</td>
</tr>
<tr>
<td>Treatment</td>
<td>9.31</td>
</tr>
</tbody>
</table>

* Significant difference between control and treatment, \( p < .05 \)

Results for the team performance and lab complexity interaction hypotheses are presented next.

*Operational Hypotheses 2.2.1*

On team lab assignment scores, the interaction effect between the TKS intervention and lab complexity will be significant.

Before running a two-way ANOVA, some manipulations were necessary in order to use the data from the lab complexity rating in the analysis. First, the individual participant six item lab complexity ratings were averaged at each measurement point. Second, the individual participant lab complexity rating averages were averaged for each team. This resulted in a lab complexity score for each team at each measurement point. Table 4.12 provides the mean lab complexity ratings and standard deviations for each lab assignment. Each lab assignment was given a complexity value based on these mean values.
Table 4.12  
Mean lab assignment characteristics ratings

<table>
<thead>
<tr>
<th>Lab Assignment</th>
<th>Complexity Rating</th>
<th>Mean</th>
<th>SD</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lab 7</td>
<td></td>
<td>3.50</td>
<td>.44</td>
<td>34</td>
</tr>
<tr>
<td>Lab 8</td>
<td></td>
<td>3.15</td>
<td>.35</td>
<td>33</td>
</tr>
<tr>
<td>Lab 9</td>
<td></td>
<td>3.45</td>
<td>.41</td>
<td>34</td>
</tr>
</tbody>
</table>

*Note: higher scores represent higher complexity ratings*

**Theme 2 Interaction Effect Results**

Two-way ANOVA was carried out to examine the interaction effect between the treatment and perceived lab complexity on lab assignment score. The IVs were “intervention type” (i.e., TKS and control) and “lab complexity” (a discrete value assigned to each lab based on student complexity ratings). The DV was team lab assignment score from zero to 10. The goal was to determine whether the effect of the intervention on team lab assignment score varied depending on the perceived lab assignment complexity.

ANOVA results show there was a significant interaction effect between intervention type and lab complexity on lab assignment score $F(2,96) = 5.06, p < .05$, partial $\eta^2 = .095$. However, the effect size for this interaction was moderate. Marginal means for control and treatment group lab assignment score at each level of complexity rating are presented in Figure 4.9.
Based on the pattern depicted in Figure 4.9, it seems that the interaction effect may be less attributable to complexity ratings and more to do with the treatment and control groups’ inverted scores on lab assignment 9. To examine this notion further, several follow up analyses were conducted. It must be noted that these follow-up analyses were exploratory in nature given the observed pattern of scores rather than based on pre-established hypotheses.

One-way ANOVA was conducted to investigate whether the differences in lab complexity ratings were significant for lab assignments 7, 8, and 9. Results of the ANOVA show that there was a significant difference in lab complexity ratings between the three lab assignments $F(2,98) = 7.55, p < .05$. The Bonferroni post hoc test was conducted to determine which complexity ratings were significantly different. Results reveal that the lab assignment 8 complexity rating significantly differed from both lab assignment 7 complexity rating and lab assignment 9 complexity rating. There was no significant difference, however, between the lab assignment 7 complexity rating and the lab assignment 9 complexity rating. In light of this, lab assignments 7 and 9 complexity ratings were combined and the two-way ANOVA was re-run with two complexity ratings: “3.15” (lab assignment 8) and “3.48” (lab assignments 7 and 9).
Two-way ANOVA was carried out to examine the interaction effect between the treatment and perceived lab complexity (now with only two levels) on lab assignment score. ANOVA results show there was no significant interaction effect between intervention type and lab complexity on lab assignment score $F(1,98) = 2.50, p = .12$, partial $\eta^2 = .025$. Marginal means for control and treatment group lab assignment score at both levels of complexity rating are presented in Figure 4.10.

![Treatment and Lab Complexity on Performance](image)

*Figure 4.10. Lab assignment scores for both lab assignment complexity levels with labs 7 and 9 combined*

Based on the means plot in Figure 4.10, it appears that lab assignment 9 scores were still bringing the overall score of the treatment group down while the scores of the control group were slightly higher for lab assignment 9. To examine this further, lab assignment 9 was removed from the analysis and the two-way ANOVA was re-run.

Two-way ANOVA was carried out to examine the interaction effect between the treatment and perceived lab complexity on lab assignments 7 and 8 score. ANOVA results show
there was no significant interaction effect between intervention type and lab complexity on lab assignment score $F(1,64) = 0.00, p = .96$, partial $\eta^2 = .000$. Marginal means for control and treatment group lab assignment score at both levels of complexity rating are presented in Figure 4.11.

![Figure 4.11. Lab assignment scores for lab assignment complexity levels with lab 9 excluded](image)

The parallel lines in the Figure 4.11 means plot support the finding that the effect of the treatment on lab assignment 7 and 8 scores did not depend on participant’s perceived lab assignment complexity. The pattern of the main effect is consistent with expectations that performance scores for the more complex lab assignments would tend to be lower. Contrary to the interaction hypothesis, however, the differences between the control group and the treatment group appear to be about the same at each level of complexity.

**Summary**

In general, the results support the main effect hypotheses for Team-SMM content and structure as well as team performance outcomes. Though results were not always significant, the
mean differences were in the expected directions. With a larger sample size it is likely that such differences would be significant. As presented, there were exceptions to these results especially for TADM mean scores and lab assignment scores. There were no significant TADM mean score differences for any of the three labs. Also, the control group significantly outperformed the treatment group on lab assignment 9 which was inconsistent with the overall pattern of TKS intervention effects. No interaction effect was evident between the treatment and number of previous lab assignments on the Team-SMM outcome variables. An interaction effect was found between the treatment and lab assignment complexity on team lab assignment performance outcome variable. Examining the interaction further revealed that the effect was more due to the contradictory findings for lab assignment 9 rather than actual lab complexity. The main and interaction effect findings with regard to the research themes, hypothesis, and relevant literature are discussed in the next chapter.
CHAPTER V: DISCUSSION

In this study, the effects of an SMM based intervention on team mental model similarity and student team performance were examined in an undergraduate meteorology laboratory course. The TKS intervention was designed using previous SMM based interventions, particularly: guided team reflexivity (Gurtner et al., 2007), coordination and adaptation training (Cannon-Bowers & Salas, 1998), interaction training (Marks et al., 2000), and team self-correction training (Blickensderfer et al., 1997). The intervention targeted five team and task related SMM factors that are: general task and team knowledge, communication skills, attitude toward teammates and task, team dynamics and interactions, and team resources and working environment (Johnson et al., 2007). The goal of the intervention was to improve team and task-related knowledge sharing processes through promoting team reflection, communication, and improvement planning thereby enhancing SMM and ultimately team performance on meteorology lab assignments.

To examine the effects of the TKS intervention, an experiment was carried out whereby student teams in an undergraduate meteorology lab (MET 1010) were randomly assigned to either a treatment or control condition. Prior to working on team lab assignments, teams in the treatment condition received the TKS intervention while those in the control condition participated in the non-TKS intervention activity. The control condition activity covered the same amount of time as the treatment condition activity but the control did not require any team interaction or SMM related tasks.

The outcome variables were Team-SMM and team performance. Team-SMM outcomes were broken down into two key elements: (1) content of team members’ perceptions regarding team and general task work and (2) team knowledge structures pertaining to team and general task work. Team-SMM content was elicited through the TADM instrument and assessed based on each team’s TADM mean score and TADM SD score. Team-SMM structure was assessed using a representational technique (Mohammed et al., 2000) where each team member rated the relationship of SMM concepts (Mathieu et al., 2000) then the closeness of these ratings was calculated via the Pathfinder program using multi-dimensional scaling (Schvaneveldt, 1990). Each Team-SMM assessment took place within the context of teams working on meteorology lab assignments. Team performance outcomes comprised team scores on three meteorology lab
assignments and a team quiz. These items were graded by the MET 1010 teaching assistants using established grading criteria.

This chapter provides a discussion of the results surrounding the two major research themes and corresponding hypotheses relative to the existing Team-SMM and performance literature. By using a between groups experimental design, comparisons between the control and treatment conditions were possible. Multivariate Analysis of Variance (MANOVA), Analysis of Variance (ANOVA), and non-parametric techniques were used to analyze differences between teams in the control and treatment conditions in terms of Team-SMM and team performance. Limitations of the present study and suggestions for future research are then discussed. Finally, the findings are then summarized in terms of the TKS intervention effects on team and task-related SMM and team performance in an undergraduate meteorology laboratory course. Based on the findings, it appears that interventions like TKS have potential for improving team performance in a higher education learning environment.

Theme 1: Effect of the TKS Intervention on Team-SMM

The SMM framework provided the theoretical basis for the design and development of the TKS intervention by drawing upon previously established SMM based interventions as well as the team and task-related five SMM factors identified by Johnson et al. (2007). Differences between the control and treatment group were expected for Team-SMM content (TADM mean scores and TADM SD scores) and Team-SMM structure score outcomes. The discovery of such differences is discussed with regard to each SMM outcome measure and corresponding hypothesis below.

Theme 1 Main Effect of the TKS Intervention on SMM

The first operational hypothesis was: for specific team lab assignments, the TADM mean score will be significantly greater for teams that receive the TKS intervention as compared to teams that do not receive the intervention. This hypothesis was based on the premise that team reflection, interaction, and self-correction would result in team improvement on critical SMM factors thus leading to higher TADM mean scores. Results failed to support the hypothesis revealing no significant differences of TADM mean scores between the treatment and control group on lab assignments 7, 8, and 9. The second operational hypothesis was: for specific team lab assignments, the TADM SD score will be significantly lower for teams that receive the TKS
intervention as compared to teams that do not receive the intervention. This hypothesis was based on the premise that team reflection and interaction would result in greater SMM similarity as indicated by lower TADM SD scores. This hypothesis was partially supported by the treatment group’s lower TADM SD score for lab assignment 7 and lab assignment 8. There was no evidence of a difference for lab assignment 9 TADM SD score. Table 5.1 summarizes the findings for theme 1 regarding the effects of the TKS intervention on SMM.

Table 5.1
Summary of control and treatment group differences on SMM outcome

<table>
<thead>
<tr>
<th>SMM Measure</th>
<th>Lab Assignment</th>
<th>Control – Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>TADM Mean</td>
<td>Lab 7</td>
<td>Ø</td>
</tr>
<tr>
<td></td>
<td>Lab 8</td>
<td>Ø</td>
</tr>
<tr>
<td></td>
<td>Lab 9</td>
<td>Ø</td>
</tr>
<tr>
<td></td>
<td>Lab 7</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>Lab 8</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>Lab 9</td>
<td>Ø</td>
</tr>
<tr>
<td>TADM SD</td>
<td>Lab 7</td>
<td>Ø</td>
</tr>
<tr>
<td></td>
<td>Lab 8</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>Lab 9</td>
<td>Ø</td>
</tr>
<tr>
<td>Team-SMM structure</td>
<td>Lab 8</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>Lab 9</td>
<td>+</td>
</tr>
</tbody>
</table>

Ø denotes no significant control and treatment group mean differences
+ denotes significantly greater SMM for the treatment group as compared to the control group

The significant control and treatment group differences for the TADM SD score but not for the TADM mean score may be attributed to two related issues: one, the difference between TADM mean score and TADM SD score in terms of what they are measuring and two, the fact that teams had worked together for three lab session prior to introducing the TKS intervention. TADM mean score represents the level of agreement with a series of statements that correspond to five SMM factors. Though the agreement score provides an indication that team members view their team with high regard on SMM factors, the score does not provide an indication of the similarity of team member mental models. The TADM mean score in this case, tends to be representing something more along the lines of mental model accuracy (Lim & Klein, 2006) or quality (Mathieu et al., 2005) as high scores would likely align with a normative model generated from experienced teams. As suggested by Mathieu et al. (2005), team processes can
suffer when team mental models are of high-quality but with low sharedness. Therefore, the TADM mean score alone may not be the best predictor of team performance.

Examining the TADM means presented in Table 4.1, it appears that teams in both the control and treatment tended to at least agree with the 15 TADM items. Based on the demographic data collected at the beginning of the semester, participants perceived themselves as having a high ability to work in a team and perceived their teammates ability to work in a team as medium to high. After the demographic data was gathered, students worked in their teams for three lab assignments prior to lab assignment 7 and the first TKS intervention. These initial perceptions of teamwork proficiency as well as time spent working together as a team may have lead to scores that more closely approximate an ideal level of team and task-related mental models. By the time the intervention was introduced, teams would have naturally worked through some of the initial stages of development (Tuckman, 1965) leading to greater and more stable TADM mean scores. This is somewhat supported by Lee and Johnson (2008) who found that in a study on the development of SMM in an undergraduate engineering course, team SMM average (similar to TADM mean) showed a greater increase between the first and second measurement points than between the second and third measurement points indicating stabilization over time. It would likely be difficult to increase such stabilized TADM mean scores with a TKS intervention that is mainly geared toward enhancing mental model similarity.

In contrast to the TADM mean score, the TADM SD score is a measure of team members’ mental model similarity with regard to team and task-related elements. Despite teams working together on three previous lab assignments, it appears that the TKS intervention was still able to have an immediate positive influence on team SMM similarity. The treatment group’s greater model similarity as indicated by the TADM SD score was consistent with previous SMM based intervention study findings (Gurtner et al., 2007; Marks et al., 2000; Smith-Jentsch et al., 1998). Marks et al. (2000) found that teams receiving interaction training showed greater SMM while Smith-Jentsch et al. (1998) found that team dimensional training (a specific form of team self-correction training) led to increased similarity of teamwork mental models. Similarly, Gurtner et al. (2007) found that guided team reflexivity enhanced the similarity of team interaction mental models.

A note about the above studies is that they all used different methods for assessing mental model similarity. Marks et al. (2000) assessed mental model similarity by determining overlap of
concepts on a concept map, Smith-Jentsch et al. (1998) had participants sort cards labeled with various team concepts then determined the similarity between each participant and to an expert model. Gurtner et al. (2007) assessed similarity through elicitation and representational techniques using the Pathfinder program which is closest to the Team-SMM Structure measure used in this dissertation study. Though these intervention studies all used different means to assess SMM and none used the TADM SD score, the results regarding the enhancement of mental model similarity through the use of an intervention are generally consistent with each other and with those found in this study. This lends support to the TKS intervention’s ability to enhance SMM as well as the TADM’s ability to measure SMM.

Consistent with the studies on interaction training, self-correction training, and team reflexivity training, the TKS intervention appears to have enhanced team SMM for lab assignments 7 and 8 as indicated by the lower TADM SD scores. These same results were not found for lab assignment 9 as there were no significant TADM SD score differences between the control and treatment groups. The control and treatment group TADM SD score means were identical for lab assignment 9 as presented in Table 4.1, though the control group TADM SD score mean decreased (greater similarity) substantially from lab assignment 8. The treatment group by contrast showed a slight increase (less similarity) in their TADM SD score from lab assignment 8. Along these lines, the TADM mean score for the treatment group was lowest at lab assignment 9. Though this result is contrary to expectations, it is consistent with the lab assignment performance data pattern. The TADM mean and SD scores as well as lab assignment performance scores indicate that lab 9 is somewhat of an anomaly with regard to the intervention effects. This will be discussed further in the section describing the effects of the TKS intervention on team performance.

The operational hypothesis regarding the intervention effects on Team-SMM structure was: for specific team lab assignments, Team-SMM Structure score calculated by the Pathfinder program will be significantly greater for teams that receive the TKS intervention as compared to teams that do not receive the intervention. This hypothesis was supported for two of the three lab assignments under study. For lab assignment 7, there were no significant differences between the control and treatment groups. For lab assignment 8, the hypothesis was supported as the treatment group had a significantly higher Team-SMM Structure score than the control group. This was also the case for lab assignment 9 after outliers were removed from the data. The
significantly greater treatment group Team-SMM Structure scores for lab assignments 8 and 9 is consistent with the literature regarding intervention effects on mental model similarity (Gurtner et al., 2007; Marks et al., 2002; Marks et al., 2000; Smith-Jentsch et al., 2001; Smith-Jentsch et al., 1998).

A possible explanation for the SMM structure similarity differences in labs 8 and 9 but not in lab 7 may be that the TKS intervention did not influence SMM structure immediately. Team and task-related SMM structure measures provide a representation of the underlying composition or organization of team SMM (Cannon-Bowers & Salas, 2001; Mohammed et al., 2000). Whereas the TADM relied upon team member responses to a series of direct statements to determine SMM content level and similarity, the Team-SMM Structure measure required team members to consider the relationship between the various concepts. The individual responses were then run through the Pathfinder algorithm (Schvaneveldt, 1990) to generate one underlying team structure similarity score (Stout et al., 1999). Thus, the structure measure is based on individual personal perceptions of team concept relatedness rather than perceptions about team members and the team in general. Given the nature of the elicitation technique (i.e., concept relatedness ratings) and the additional representation technique (i.e., Pathfinder algorithm) it can be argued that Team-SMM structure is somewhat deeper and more stable than Team-SMM content making it more difficult to influence through such means as an SMM based intervention.

Describing SMM structure specifically, Cannon-Bowers and Salas (2001) state that “when team members are similar in their organization of knowledge, it will enable them to generate shared knowledge during the task” (p.199). Though content elicitation data can be quantified to determine the similarity between team members, it does not tap into the underlying organizational structure of the team’s knowledge domain (Mohammed et al., 2000). Therefore, SMM content differences were evident following the first administration of the intervention as indicated by significantly lower (more similar) TADM SD scores for the treatment group. These differences were also present for lab assignment 8 though not for lab assignment 9. Conversely, SMM structure differences were not evident after the first administration of the intervention but were present for lab assignments 8 and 9. This lends support to the notion that SMM structure as measured in this study is more difficult to influence and consequently more stable than the SMM content.
Theme 1 Interaction Effect between TKS Intervention and Previous Lab Assignments

The possible interaction between the TKS treatment and number of previous lab assignments on performance score is discussed in this section. The interaction hypothesis was: on Team-SMM scores, the interaction effect between the TKS intervention and the number of previous team lab assignments will be significant. This hypothesis was based on two possible outcomes that would reveal a significant interaction effect. The first outcome relates to team-self correction over time since a main part of the TKS intervention involved team self-correction (Blickensderfer et al., 1997). Teams were instructed to identify points of weakness in terms of critical SMM factors then suggest strategies for how to correct those weaknesses. Though the benefits of self-correction may not have been evident immediately, the treatment group was expected to eventually show more similar SMM scores.

The second possible outcome relates to an expected natural change in SMM over time independent of the TKS treatment effects. Previous studies have found mixed results regarding change in Team-SMM over time. Lee and Johnson (2008) found that Team-SMM average and similarity generally developed among student teams over three team performance episodes in an undergraduate engineering course. In two repeated measures studies using a flight simulation, Mathieu et al. (2005) and Mathieu et al. (2000) found that mental model similarity remained stable over three subsequent measurement points. Levesque et al. (2001) found that Team-SMM actually decreased over time among software development project team members. Since this dissertation study most closely approximates that of Lee and Johnson (2008) in its examination of student teams in the academic setting, it was expected that SMM would naturally increase over time for both the treatment and the control group thereby diminishing the effects of the intervention over subsequent lab assignments.

The results from the meteorology study revealed no significant interaction effect between the intervention and number of previous lab assignments for any of the Team-SMM outcome variables. Examination of the means in Table 4.1 shows a substantial decrease in the control group’s TADM SD score (indicating an increase in SMM) from lab assignment 8 (four previous team lab assignments) to lab assignment 9 (five previous team lab assignments). This increase in SMM is consistent with the natural changes over time found by Lee and Johnson (2008). There is also a notable decrease (greater similarity) in the treatment group’s SMM as indicted by the increased TADM SD score from lab assignments 8 to lab assignment 9. These differences are
most likely attributed to the main effect for lab assignment 9, however, and do not appear to be a part of any interaction pattern between the TKS intervention and the number of previous lab assignments.

Based on the overall means in Table 4.1 and the ANOVA results comparing the combined control and treatment SMM outcomes across the three lab assignments, it appears that there were no significant changes in SMM over time. This is consistent with the findings of Mathieu et al. (2005) and Mathieu et al. (2000). Consequently, the TKS intervention impact does not systematically vary over the three consecutive lab assignments. Therefore, the effect of the intervention does not appear to depend on the number of previous lab assignments in this study. Perhaps the result would have been different if the intervention was applied and data was gathered over a longer time period such as an entire semester.

In general, the TKS intervention was effective for enhancing team mental model similarity as evidenced by lower TADM SD and higher Team-SMM Structure scores for the treatment group on most lab assignments. This result is consistent with the existing literature on the ability of SMM based interventions to enhance Team-SMM. There were no significant differences between the treatment and control group for TADM mean scores. This is likely explained by the nature of the instrument in its possible measurement of SMM quality rather than similarity and the fact that teams had worked together on three lab assignments prior to receiving the intervention. That is, as teams worked together early in the semester their mental model quality and represented by the TADM mean score reached a point that was difficult to influence with the TKS intervention. Based on the lack of significant findings for the interaction hypothesis, it appears that the effect of the TKS intervention on Team-SMM does not depend on the number of previous lab assignments.

Theme 2: Effect of the TKS Intervention on Team Performance

The effect of the TKS intervention on team performance is discussed in this section. A theoretical and empirical link has been established between SMM and team performance (Banks & Millward, 2007; Edwards et al., 2006; Lee & Johnson, 2008; Mathieu et al., 2000; Stout et al., 1999). Research has also established that SMM based interventions can lead to greater team performance in various settings (Gurtner et al., 2007; Marks et al., 2002; Salas et al., 2007; Smith-Jentsch et al., 1998; Stout et al., 1997). Based on this empirical evidence, differences
between the control and treatment group were expected for team lab assignment performance and team quiz performance outcomes. The discovery of such control and treatment group differences is discussed with regard to these outcomes and corresponding hypothesis below.

Theme 2 Main Effect of the TKS Intervention on Performance

The main effect hypothesis regarding team performance was: on specific meteorology team lab assignments and the team quiz, teams that receive the TKS intervention will score significantly higher than teams that do not receive the intervention. The results for this hypothesis were mixed for the three lab assignments under study. For lab assignment 7, results failed to show a significant difference between the treatment and control group though, consistent with expectations, the mean scores were slightly higher for the treatment group. For lab assignment 8, the treatment group’s mean score was significantly greater than that of the control group which supports the hypothesis. There was also a significant difference between the treatment and control group for lab assignment 9, though the control group’s mean score was greater than the treatment group which is in contrast to the hypothesis. Consistent with the hypothesis, the treatment group’s mean team quiz score was significantly higher than that of the control group with the one outlier removed from the analysis.

To determine whether lab assignment 9 score was truly breaking from the pattern of the treatment group outperforming the control group, lab assignment 12 scores were examined since this was the team lab assignment that most immediately followed lab assignment 9. Though the results were not significant for lab 12, the treatment group’s mean score was once again higher than that of the control group. In light of these results, two main findings warrant further discussion: (1) the lack of significant differences between the treatment and control for lab assignment 7 yet means that are consistent with expected outcomes, and (2) the control group scoring significantly higher than the treatment group on lab assignment 9 therefore breaking from the overall performance results pattern.

The treatment group had a higher average team lab assignment 7 score than the control group. Though the results were not significant at the .05 level, the $p$ value is approaching significance ($p = .09$) with a moderate effect size (partial $\eta^2 = .085$). One simple explanation for the lack of significance may be the low sample size ($n = 34$) and it could reasonably be expected that more teams would increase the chances of rejecting the null hypothesis. Despite the low sample size, significant differences for lab assignments 8 and 9 were found between the
treatment and control groups. Table 5.2 summarizes the findings for theme 2 regarding the effects of the TKS intervention on team performance.

Table 5.2
Summary of control and treatment group differences on team performance outcome

<table>
<thead>
<tr>
<th>Performance Measure</th>
<th>Lab Assignment</th>
<th>Control – Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lab Assignment Score</td>
<td>Lab 7</td>
<td>Ø</td>
</tr>
<tr>
<td></td>
<td>Lab 8</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>Lab 9</td>
<td>-</td>
</tr>
<tr>
<td>Team Quiz Score</td>
<td>n/a</td>
<td>+</td>
</tr>
</tbody>
</table>

Ø denotes no significant control and treatment group mean differences
+ denotes significantly greater team performance for the treatment group as compared to the control group
- denotes significantly greater team performance for the control group as compared to the treatment group

As discussed in the previous section, there were no significant treatment and control group differences for the lab assignment 7 Team-SMM Structure scores through the means were higher (more similar) for the treatment group. There were significant structure score differences for lab assignments 8 and 9 with the treatment group means being higher (more similar) than the control group. An opposite pattern was seen for the TADM SD where the treatment group had lower (more similar) scores for lab assignments 7 and 8 but no significant differences were found for lab assignment 9.

The explanation for this opposite pattern for the Team-SMM Structure and TADM SD scores was that Team-SMM structure may be a deeper and more stable measure of mental model similarity than the TADM SD thereby making it more difficult to impact immediately with an intervention. The same type of explanation may be valid for team lab assignment performance where the TKS intervention had a slight impact on the treatment teams for lab 7 but not enough to indicate a statistically significant difference given the low sample size. Considering that team processes have been found to mediate the relationship between mental model similarity and team performance (Klimoski & Mohammed, 1994; Marks et al., 2000; Mathieu et al., 2000), the TKS process intervention may have enhanced team processes immediately but the significant impact on performance scores was somewhat delayed.
For lab assignment 12, the treatment group also outscored the control group though these differences were once again not significant. A plausible explanation for the lack of significant control and treatment group differences for lab assignment 12 is the three week time interval between the last TKS intervention administration at lab assignment 9 and lab assignment 12 which did not include a TKS intervention. To date, studies have not examined intervention retention effects after stopping an intervention following several repeated administrations. There is evidence, however, to support the benefits of administering an intervention prior to each performance episode (Marks et al., 2000) as well as providing several experiences with an intervention (Smith-Jentsch et al., 1998) in order to enhance SMM and improve team performance. Repeated administrations appear to result in a general pattern of greater SMM and team performance for the TKS treatment group in the present study though lab assignment 9 deviates from this pattern as discussed next.

Given the empirical evidence regarding the positive impact of SMM based interventions on team performance and the lab assignment 7 and 8 performance score means, it was surprising to see that the control group significantly outperformed the treatment group on lab assignment 9. This result is contradictory to the stated hypothesis as well as the overall pattern of the treatment group outperforming the control. Though the result was not significant for a non-parametric Mann-Whitney U test, the p value of .06 indicates the differences were close to significant.

In the context of this study, there are two possible related explanations for this result. The first has to do with unique events that took place for team lab assignment 9. Lab assignments 7 and 8 as well as the team quiz were structured in a way that allowed teams to work at a table exclusively in the lab setting on the specified tasks. This was also the case for lab assignment 12 later in the semester. The instructional mode for lab 9 was different from the other labs included in this study. In lab assignment 9, students proceeded to the meteorology building roof to observe the launch of a weather balloon for 10 minutes immediately following the TKS intervention. Given the limited instruments and task requirements, there was some re-shuffling of team members in order to be sure every student could participate in the observation task. After the observations, students returned to the lab environment, the existing teams were re-formed and these teams began work in answering the questions in the lab manual. This temporary reshuffling of the teams following the TKS intervention, the unique lab requirements, and the
reforming of the teams in the lab following the roof activity are all possible factors that contributed to the unexpected performance results.

Though the proposed lab 9 explanation intuitively makes sense, it is somewhat contradicted by Marks et al. (2000) who administered team-interaction training before each of three performance episodes. The first performance episode took place in a familiar environment whereas the latter two episodes took place in novel environments which were physically different from the training and routine environments and that required different performance strategies for success. In the Marks et al. (2000) study, teams in the treatment condition displayed greater SMM, mental model accuracy, communication, and performance for each performance episode. Moreover, the effects of the intervention were more pronounced in the two novel environments. The authors state that “in ill-defined and rapidly changing environments, there is a need for cognitive structures that allow for immediate and synergistic reactions for teams to adaptively respond to their environment in pursuit of their goals….. When teams perform in novel or unfamiliar environments, as long as members are in sync with their teammates (i.e., share a common framework on how to perform), they do not have to depend on having an a priori accurate depiction of strategies effective in a novel domain” (Marks et al., 2000, p. 982). Along these lines, it would seem that the greater SMM among the meteorology treatment group teams as evidenced by the lab assignment 8 TADM SD and Team-SMM Structure scores would allow these teams to adapt and perform well on lab assignment 9 despite its novelty.

One thing to consider is that although the simulated environment and certain tasks changed for each performance episode in the Marks et al. (2000) study, all teams were trained on the skills required to succeed in the new environments. In the MET 1010 lab, by contrast, the environment and consequent tasks required a new set of skills (such as tracking a balloon in the sky) that participants had no experience with prior to the lab. Therefore, teams had to learn a new set of task in a novel environment with unfamiliar tasks. This coupled with treatment group teams having to re-define their established roles, as explained next, likely contributed to a drop in the treatment group’s performance.

A related explanation for the inconsistent lab 9 findings may have to do with the divisible versus unitary nature of the lab assignment tasks. Steiner (1972) describes divisible tasks as those in which a division of labor is feasible, such as building a house. Unitary tasks are those
that cannot be profitably divided into subtasks, such as engaging in a group discussion. As indicated in the method section, the MET 1010 lab teaching assistants on average rated the tasks in lab assignment 9 as more unitary than those in lab assignments 7 and 8. With lower scores representing more unitary and higher scores representing more divisible, lab assignment 7 was given a mean rating of 7.25, lab assignment 8 was given a mean rating of 8.50, and lab assignment 9 was given a mean rating of 3.50. Lab assignment 12 was given a mean rating of 6.75 which is more consistent with lab assignments 7 and 8 in its proximity to the divisible end of the scale. These differences in the nature of lab tasks relative to team member roles offers a possible explanation for the observed performance score differences for lab 9 as well as the lack of TADM SD differences for lab assignment 9.

Cannon-Bowers et al. (1993) state that team members take on specific roles that are clearly defined and differentiated with regard to responsibilities. It is the heterogeneity of expertise, roles, and responsibilities that truly defines a team. According to Steiner (1972), rules governing task processes and consequently decisions about role assignment will differ depending on whether the task is unitary or divisible. Establishing explicit roles and training team members in each role has been found to positively impact team SMM, processes, and performance (Marks et al., 2002). Though not directly observed in the present study, it is likely that team members took on roles for lab assignments 7 and 8 that corresponded to the tasks being divisible. When the treatment group was presented with the more unitary lab assignment 9, the mental models they had developed in the context of divisible roles no longer applied. This may have impacted the treatment group’s SMM content and performance as indicated by the higher TADM SD score and lower lab 9 assignment scores respectively. The fact that lab 9 Team-SMM Structure scores were not impacted was likely due to the stability of this measure as discussed previously. In returning to the more divisible lab assignment 12, though not statistically significant, the treatment group’s mean performance scores were greater than the control group scores which was once again consistent with expectations.

This decrease in performance for the treatment group on the unitary lab underlines the necessity of having consistent activities throughout an entire unit or course when team-learning strategies are being used (Michaelsen et al., 2002). Along these lines, McInerney (2003) found that when there was an incongruence between material covered in the examinations and quizzes and that covered in the team activities, teams showed high activity performance scores but low
examination and quiz scores. When the incongruence was resolved, students displayed high performance on all lab activities, examinations, and quizzes. Though further research is necessary to determine if the TKS intervention performance improvement potential depends on the divisibility of lab tasks, it is plausible that incongruence of lab assignments lead to a degradation of treatment group performance. The control group was not affected, as indicated by their continued natural trend of increased performance score, since their SMM was not as well established.

**Theme 2 Interaction Effect between the TKS Intervention and Lab Complexity**

The possible interaction between the TKS treatment and lab assignment complexity on performance score is discussed in this section. The interaction hypothesis for the second theme was: on team lab assignment scores, the interaction effect between the TKS intervention and lab complexity will be significant. This hypothesis was based on the theoretical and empirical link between SMM and team performance for high complexity tasks. It has been stated that teams can pool their resources to work on tasks that are too complex and/or too large to be handled by one person (Cooke, Salas, Kiekel, & Bell, 2004; Eccles & Tenenbaum, 2004; Stout, Cannon-Bowers, Salas, & Milanovich, 1999). Further, most of the evidence for the link between SMM and team performance has come out of high stress and high intensity environments where task performance can be highly complex (e.g. Klimoski & Mohammed, 1994; Mathieu et al., 2000; Salas & Fiore, 2004). Empirical studies have also found that SMM based interventions can enhance team performance on complex tasks in high intensity environments (e.g. Cannon-Bowers & Salas, 1998; Smith-Jentsch et al., 1998; Stout et al., 1997). Entin and Serfaty (1999) found specifically that the effect of team coordination training yielded the greatest performance benefit for teams that were under stress in a combat situation.

Based on the above studies, it was expected that greater SMM would allow teams to perform well despite task complexity while the control group would experience a decline in performance for complex labs. Though the results revealed a significant interaction between the intervention and lab complexity initially, this effect appeared to be more related to the inverted scores on lab assignment 9 rather than lab complexity. Lab assignment 9 was not significantly rated as more complex than lab assignment 7 though they were both significantly more complex than lab assignment 8. Lab assignment 8 was rated as least complex but showed greater SMM content and structure as well as performance for the treatment group. When lab assignments 7
and 9 were combined, the interaction was no longer significant. Removing lab assignment 9 from the analysis revealed similar performance score declines for the control and treatment group when the lab assignment was more complex. Thus, there was no significant interaction effect with lab assignments 7 and 9 combined or with lab 9 removed.

This lack of significant finding may be explained by the differences in environmental intensity between the previously mentioned studies (Cannon-Bowers & Salas, 1998; Entin & Serfaty, 1999; Smith-Jentsch et al., 1998; Stout et al., 1997) and this study. Though lab assignments differed in complexity, the MET 1010 lab environment likely does not match the intensity that would be present in a military scenario such as flight (Entin & Serfaty, 1999; Gurtner et al., 2007), tank combat (Marks et al., 2002; Marks et al., 2000), or shipboard (Smith-Jentsch et al., 1998) simulations. Also, Lim and Klein (2006) suggest that the main reason they found a link between SMM and performance was due to the fact that the teams examined in the study were expected to perform in high stress environments under intense time pressure on a regular basis. In this type of environment, SMM are theorized to have the greatest predictability for team performance given that there is little time for explicit coordination and communication (e.g. Klimoski & Mohammed, 1994; Salas & Fiore, 2004). Finally, it is noteworthy that team adaptation training was used in the Entin and Serfaty (1999) study. This strategy is designed specifically to enhance mental model similarity and reduce communication overhead thereby allowing teams to adapt and perform to their capabilities in highly intense and complex situations. The TKS intervention focused more on team reflexivity, communication, and self-correction than team adaptation. Thus, even if the MET 1010 environment was sufficient in intensity, the intervention employed may not have prepared teams to adapt accordingly. The next section describes the task intensity and complexity limitation and several other limitations associated with this study.

Study Limitations

Though this study generated useful information in answering the question regarding the impact of the TKS intervention on team SMM and performance, there are certain theoretical and design limitations that require discussion. The theoretical limitations have to do with lab intensity, performance score ceiling effects, and specificity of the intervention. The design

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limitations have to do with sample size, student absenteeism, the intervention time period, performance outcomes, and process quality measures.

The first theoretical limitation is that, although MET 1010 lab tasks may be too complicated and large to be handled by an individual, the environment is not necessarily one of high-intensity where SMM has found to directly link to performance (e.g. Klimoski & Mohammed, 1994; 2004). This limitation was discussed in the above section regarding to the lack of significant findings for an interaction effect between the intervention and lab complexity on the lab assignment performance outcome. The limitation, however, is directly related to the main study question regarding the applicability of the SMM framework for introducing interventions in an academic setting like MET 1010. Though complexity may be high for some tasks, intensity is generally lower than in environments such as military combat simulations. It would be useful for future studies to vary the level of lab intensity and hypothesize according to this variation.

In a matter related to lab assignment complexity, lab assignment performance scores were generally high for both the treatment and control group. A possible ceiling effect may be occurring which is represented by the negative skew of the performance score distribution. Based on personal conversations with the MET 1010 teaching assistants, the high performance scores on lab assignments were likely due to a tendency to reward completeness and effort as well as accuracy. Though the possible inflated grades cause some concern over the validity and sensitivity of the performance measure, standardized grading criteria and the fact that there were significant differences between the treatment and control group reduces these concerns. Also, the treatment group significantly outperformed the control group on the team quiz on which the performance scores were more normally distributed, means were generally lower, and there was only one perfect score out of all 34 teams.

Another limitation of this study is shared by Stout et al. (1997) who found team training to be effective for 42 aviators. The authors state that given the “multiphasic approach to training and evaluation that was used, it is not possible to determine what specific aspect of training enhanced which specific competency” (p. 180). Similarly, the TKS intervention in this dissertation study did not target specific aspects of the lab assignments that were perhaps more challenging, required certain team member roles, etc. Also, like team-interaction training used by Marks et al. (2000), the TKS was essentially designed to help members work better as a team,
not how to perform the task requirements better per se. Though the TKS intervention is slightly more specific in its targeting of SMM factors than the approach used by Stout et al. (1997), further intervention refinement based on team needs and task specifications is suggested for the future research.

The first design limitation is low sample size. Despite having approximately 112 participants, the sample size was reduced given that teams are the unit of analysis. This resulted in 34 teams for the entire study with 17 teams in the treatment condition and 17 teams in the control condition. A sample size equal to or greater than the ideal 20 per condition (Mertler & Vannatta, 2002) may have led to significant findings for treatment and control group differences in Team-SMM Structure and lab assignment 7 performance scores. Though the means for these outcomes were in the expected direction, the differences were not significant. A theoretical explanation for this result in terms of delayed effect of the intervention was offered above but low sample size may also be a viable explanation. Given these low numbers, this study used a between groups experimental design with only a treatment and control group. It is uncertain whether the effects of the intervention on SMM and performance were due to the exact nature of the intervention or simply due to the fact that the treatment groups engaged in a team activity of some type while the control group did not.

There was also the limitation of student absenteeism from specific labs. In one case, student absenteeism resulted in missing data from an entire team for lab assignment 8. It could be argued that individual team member absenteeism on lab assignments 7, 8, and 9 lessened the intervention’s impact if the TKS was completed without all team members present. Also, if team member absenteeism during work on lab assignment tasks changed the team dynamics, it may have influenced responses to the SMM measures as well as the performance capabilities of that team. These issues were likely equally distributed across the treatment and control conditions with random assignment to teams though a larger sample size would provide stronger support for this claim. Absenteeism is an inherent part of the real-world classroom setting, however, and is a consequence of conducting a study in a natural environment rather than a controlled lab setting.

Another design limitation is that the intervention was introduced only for lab assignments 7, 8, and 9. The main reason for choosing to examine only these assignments was the time constraints imposed by the nature of the MET 1010 course. The teaching assistants were responsible for covering a lot of material and engaging students in activities over a specified time
period. Introducing the intervention for each team lab assignment, at 15 minutes each, would have cut into this time period and students would have potentially missed out on learning opportunities. This was especially a concern when it was not certain whether the intervention would be effective. Only looking at three lab assignments did not allow for an examination of the intervention effects at the start of the semester when teams were newly formed and how these effects endured over the course of an entire semester. Despite this limitation, lab assignments 7, 8, and 9 represented a comprehensive set that resulted in useful data for answering the research questions using a between groups experimental design without encroaching too severely on time in instruction.

Neither task-specific SMM nor individual student performance was examined in this study. Though this is not necessarily a limitation given that the focus of the study was on teams, it could be argued that Task-SMM and individual student performance are stronger indicators of student learning. This would especially be the case with lab assignment tasks that are more divisible in nature. Students dividing up the workload may lead to greater Team-SMM and ultimately performance as team members take on roles and use the strengths of each member to accomplish the objectives. It is not clear, however, whether each student is learning all the material or just their own specific piece. In the future, researchers may want to consider student learning outcomes specifically, which are a different focus than the team performance outcomes examined in this study.

Finally, this study does not directly measure team processes quality. Theoretically, team processes mediate the relationship between SMM and performance (Edwards et al., 2006; Klimoski & Mohammed, 1994). Several empirical studies have supported the existence of this relationship (Heffner, 1998; Mathieu et al., 2000) as well as finding that SMM based interventions can improve team processes (Marks et al., 2000; Smith-Jentsch et al., 1998). The relationship between SMM and team processes supports that notion that SMM measures provide at least an indirect measure of team processes. Based on the significant findings for the SMM measures and team performance in the present study, it appears that the TADM and Team-SMM are valid indicators of team processes despite the fact that they are not direct measures.
Future Research

This study generated interesting results regarding differences between the control and treatment groups on Team-SMM and team performance. It is suggested that future studies replicate this dissertation study within the MET 1010 lab setting to make a more powerful claim regarding the effect of the TKS intervention in this environment. Increasing the sample size with a replication study may generate significant findings in areas where there were none, such as lab assignment 7 SMM structure and assignment score. Such a replication study would also determine if the inverse pattern for lab assignment 9 is one that persists or whether it was unique to this study.

There are several opportunities for future research that can use the TKS intervention in MET 1010 or a similar learning setting. To examine the effects of the intervention on Team-SMM and performance early in a semester and throughout the entire semester, it would be beneficial to introduce the intervention during the first team lab assignment and for each subsequent lab assignment. If time constraints prevent this, perhaps the intervention could be introduced at certain points during the semester such as the beginning, middle, and end. Though looking at longitudinal effects involves somewhat different research questions than those posed in this study, it is anticipated that such questions would be of interest to researchers studying SMM based interventions in the team-learning environment. It would also be beneficial to get a better understanding of the TKS intervention effects on individual student and team learning. To accomplish this, Task-SMM and individual performance as outcome variables could be included in future studies where the TKS intervention is applied.

The TKS intervention targets team processes relative to the five factor SMM model (Johnson et al., 2007) in order to enhance mental model similarity and ultimately performance. Therefore, it would be extremely useful for future studies to directly assess team process quality relative to these five factors while working on lab assignments. Videotaping team interaction then having experts rate process quality by reviewing the videos (see Mathieu et al., 2000), though a major undertaking, would be a useful strategy for directly examining the effect of the TKS intervention on team processes. Team process results could help explain SMM and performance results that are inconsistent with expectations, such as those of lab assignment 9 in this study.
A main limitation of this study is that it only used a treatment and control condition. Despite seeing significant effects of the intervention, these effects could simply be due to the fact that the treatment group engaged in a team activity while the control group worked individually. It is suggested that future studies use TKS treatment, comparison, and control groups. The comparison group activity could involve another SMM activity, such as task related knowledge sharing or pre-task process coordination planning which would likely be useful in such a case where tasks shift from divisible to unitary. More simply, a non-SMM team activity could be used such as those described in the ASTD team development sourcebook (Silberman & Phillips, 2005).

There are also several opportunities for research using the TKS intervention and others like it in settings beyond those similar to MET 1010 and possibly beyond higher education. One opportunity is to examine the intervention effects in a controlled research lab setting where task complexity, intensity, and duration as well as team factors such as personality and team size can be controlled. If such effects can be replicated for a variety of teams and tasks, the TKS intervention could potentially be adopted for use by practitioners in a number of settings. As understanding of its effects develops, the intervention can be introduced at strategic intervention points depending on when it is found to be most effective. Ultimately, a more precise version of the TKS can be introduced at times when teams are lagging on particular SMM factors as indicated by the TADM.

Conclusions

Teams are being used within various organizations to work on complex tasks and achieve goals that may be unattainable by any one individual (Cooke et al., 2004; Eccles & Tenenbaum, 2004; Mathieu et al., 2000; Salas & Fiore, 2004; Stout et al., 1999). Teams consist of two or more members who interact cooperatively and adaptively in pursuit of shared and valued objectives (Cannon-Bowers et al., 1993). When functioning properly, teams offer such benefits as increased flexibility, creativeness, and diversity of perspectives. In a business setting, improper team functioning can result in lost revenue for an organization (Guzzo & Dickson, 1996). In a high-intensity setting such as military combat, improper team functioning can result in dire consequences such as loss of life (Stout et al., 1999). Therefore, a substantial research effort has focused on understanding the mechanisms that drive team processes and performance.
At the forefront of this effort is the SMM framework (Cannon-Bowers et al., 1993) where it is stated that similarity of team mental models is a strong predictor of team performance (Banks & Millward, 2007; Edwards et al., 2006; Lee & Johnson, 2008; Mathieu et al., 2000; Stout et al., 1999). It has also been found that SMM based interventions have the potential for enhancing team mental model similarity and ultimately performance in various settings (Gurtner et al., 2007; Marks et al., 2002; Salas et al., 2007; Smith-Jentsch et al., 1998; Stout et al., 1997). Though Mohammed and Dumville (2001) state that the team SMM framework can be applied across disciplines, research has been lacking in the application and empirical investigation of SMM based interventions in an academic setting where cooperative / collaborative learning (Slavin, 1987, 1996), PBL (Savery & Duffy, 1995), and TBL (Michaelsen et al., 2002) strategies are being utilized. Johnson et al. (2008) assert that the SMM framework has great potential to be applied and examined in the team-learning academic environment.

The objective of this study was to determine if an SMM based intervention could enhance Team-SMM ultimately leading to greater team performance in an academic setting where team-learning strategies are being used. The TKS intervention applied in this study drew upon previously established SMM based interventions related to team reflection (Gurtner et al., 2007), communication and coordination (Entin & Serfaty, 1999), and self-correction (Blickensderfer et al., 1997) as well as the five factor model SMM model (Johnson et al., 2007). By administering the TKS intervention to teams in the treatment condition, it was expected that they would have greater SMM and performance scores than teams in the control condition that did not receive the TKS intervention. Team-SMM was assessed in terms of content via the TADM instrument (Johnson et al., 2007) as well as structure via the Team-SMM structure (Cannon-Bowers & Salas, 2001) instrument and Pathfinder algorithm (Schvaneveldt, 1990). Team performance was determined by obtaining a team scores on three consecutive lab assignments and a team quiz.

The treatment group showed greater mental model content similarity as measured by TADM SD scores for lab assignments 7 and 8. As indicated by the Team-SMM structure score, the treatment group showed greater mental model structure similarity for lab assignment 8 and 9. The reason for this discrepancy is likely attributed to the depth and stability of SMM structure rendering it more difficult to influence that SMM content. The treatment group showed significantly greater performance scores than the control group on lab assignment 8 and the team quiz. Treatment group performance score means were noticeably higher for lab assignment 7.
though results were not significant. This may be explained by delayed effects of the intervention on performance much like with SMM structure. For lab assignment 9, the control group outperformed the treatment group. This result contradicted the stated hypothesis and required further investigation. It appears that the likely causes for the unexpected lab assignment 9 findings were a series of unique events taking place during the lab as well as the unitary structure of that lab. The SMM developed by the treatment teams during lab assignments 7 and 8 may have been rendered invalid when presented with the unique events and unitary structure of lab assignment 9. This notion was supported by means that were once again consistent with expectations for lab assignment 12 for which tasks were rated as divisible in nature. This finding regarding lab assignment structure underlines the necessity of consistent team assignments as described in the TBL framework.

Overall, this study found that the TKS intervention generally enhanced Team-SMM and team performance in the MET 1010 course. The treatment group’s mental model similarity was generally higher for all three lab assignments. The treatment group’s performance score mean was significantly greater for lab assignment 8 and the team quiz. The treatment group’s mean performance score was also higher for lab assignments 7 and 12 though this difference was not significant. Despite lab assignment 9 standing out as an anomaly, it provides a rich area for future research regarding the structure of activities in the learning environment. Overall, the treatment group significantly outperformed the control group when pooling the performance measures of lab assignments 7, 8, 9, and 12 and the team quiz.

These results build on the existing literature that examines the relationship between SMM and team performance while supporting the potential of SMM based interventions for enhancing team mental model similarity and performance. More specifically, the results highlight the potential for using the TKS intervention or similar SMM based interventions in team-learning environments such as MET 1010. Previous studies had not examined the effects of an SMM based intervention in an academic setting where team-learning strategies were being used. The results of this study make a good case for an instructor employing such an intervention to elicit greater performance from student teams.

This dissertation study represents just one possible path that connects to a major line of research that is SMM and team performance. Though there are limitations associated with this study, each limitation presents an opportunity for future research related to SMM, interventions,
and team performance. It is important for researchers to explore the possible paths in order to better understand and ultimately improve team functioning in the team-learning environment and beyond.
APPENDIX A: INTERVENTION TASK

Part I
THIS EXERCISE IS TO BE COMPLETED INDIVIDUALLY (5 minutes)

Your name: ____________________________

Date: ____________________________ Lab # and name: ____________________________

Please respond to each of the following statements by circling the appropriate response. Be sure to respond to all statements before moving on to the “team ratings” portion of the activity. You have 5 minutes to complete this exercise.

1. My team understands each lab task that we perform

<table>
<thead>
<tr>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Somewhat Agree</th>
<th>Neutral</th>
<th>Somewhat Disagree</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
</table>

2. My team uses effective team processes

<table>
<thead>
<tr>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Somewhat Agree</th>
<th>Neutral</th>
<th>Somewhat Disagree</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
</table>

3. Members within my team communicate information effectively

<table>
<thead>
<tr>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Somewhat Agree</th>
<th>Neutral</th>
<th>Somewhat Disagree</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
</table>

4. Members within my team have a positive attitude toward one another

<table>
<thead>
<tr>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Somewhat Agree</th>
<th>Neutral</th>
<th>Somewhat Disagree</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
</table>

5. My team approaches lab tasks with a positive attitude

<table>
<thead>
<tr>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Somewhat Agree</th>
<th>Neutral</th>
<th>Somewhat Disagree</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
</table>

6. Members within my team understand how to interact with one another

<table>
<thead>
<tr>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Somewhat Agree</th>
<th>Neutral</th>
<th>Somewhat Disagree</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
</table>
7. My team uses resources (e.g. notebooks, computers, etc.) effectively to work on lab tasks

<table>
<thead>
<tr>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Somewhat Agree</th>
<th>Neutral</th>
<th>Somewhat Disagree</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
</table>

8. My team realizes the constraints of the working environment (e.g. time, resources, etc.)

<table>
<thead>
<tr>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Somewhat Agree</th>
<th>Neutral</th>
<th>Somewhat Disagree</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
</table>
Part II

THIS EXERCISE IS TO BE COMPLETED AS A TEAM (5 minutes)

Team member names:

Date:       Lab # and name:

As a team, please respond to each of the following statements by circling the appropriate response. Be sure to reach a consensus on all statements by discussing each team member’s individual response and their rationale for that response. You have 5 minutes to complete this portion of the exercise.

1. Our team understands each lab task that we work on

<table>
<thead>
<tr>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Somewhat Agree</th>
<th>Neutral</th>
<th>Somewhat Disagree</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
</table>

2. Our team uses effective team processes

<table>
<thead>
<tr>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Somewhat Agree</th>
<th>Neutral</th>
<th>Somewhat Disagree</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
</table>

3. Members within our team communicate information effectively

<table>
<thead>
<tr>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Somewhat Agree</th>
<th>Neutral</th>
<th>Somewhat Disagree</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
</table>

4. Members within our team have a positive attitude toward one another

<table>
<thead>
<tr>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Somewhat Agree</th>
<th>Neutral</th>
<th>Somewhat Disagree</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
</table>

5. Our team approaches tasks with a positive attitude

<table>
<thead>
<tr>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Somewhat Agree</th>
<th>Neutral</th>
<th>Somewhat Disagree</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
</table>

6. Members within our team understand how to interact with one another

<table>
<thead>
<tr>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Somewhat Agree</th>
<th>Neutral</th>
<th>Somewhat Disagree</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
</table>
7. Our team uses resources (e.g. notebooks, computers, etc.) effectively to work on lab tasks

<table>
<thead>
<tr>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Somewhat Agree</th>
<th>Neutral</th>
<th>Somewhat Disagree</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
</table>

8. Our team realizes the constraints of the working environment (e.g. time, resources, etc.)

<table>
<thead>
<tr>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Somewhat Agree</th>
<th>Neutral</th>
<th>Somewhat Disagree</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
</table>

Part III

THIS EXERCISE IS TO BE COMPLETED AS A TEAM (5 minutes)

Given your team’s performance on lab assignments thus far, circle the two areas where your team can improve the most. Be sure to reach a consensus by discussing each team member’s individual opinion.

1. Team understanding of lab tasks
2. Team process for working on lab tasks
3. Team member communication of information
4. Team member attitude toward each other
5. Team attitude toward tasks
6. General team member interaction
7. Team use of resources (e.g. notebooks, computers, etc.)
8. Team realization of working environment constraints (e.g. time, resources, etc.)

Now, discuss and write down (i.e., in one or two sentences) your team’s suggestions for how you can improve in the areas you circled above (NOTE: there is always room for improvement).

**Improvement Potential Area 1:**
Suggestions for how to improve in this area:

**Improvement Potential Area 2:**
Suggestions for how to improve in this area:
It never rains at Tallahassee's airport (and other weather myths)
By Gerald Ensley

Everyone talks about the weather — whether we understand it or not.

I think about that when someone comes running in to say a storm is brewing in the east — though most of Tallahassee's weather comes from the west. I also think about it when my golf partners and I argue about why it never seems to rain on our side of town — after it's poured on another part of town. That's what happened June 25. That Wednesday afternoon, we got torrential rain at the newspaper but got barely a drop at my house. That night, we got nearly 4 inches at my house while friends on the other side of town said they had only a light rain. That led to another discussion Saturday on the golf course. One of us who, ahem, got a B in college meteorology said the cause was the "heat of the city." As storm clouds pass over Tallahassee, the heat from downtown releases moisture in the clouds. That's why it rains like heck on the east-side Democrat and not on my west-side home. Apparently, it's also why I got only a B in meteorology.

Yes, studies have shown the heat from the urban pavement and traffic emissions cause more lightning and rain on the downwind side of cities. But those studies were in big metropolitan areas such as Baltimore-Washington and Dallas-Fort Worth. It would be laughable — if I read Bob Goree's suppressed chuckles correctly — to think that's happening here. Though there have been no specific studies of Tallahassee, Goree said we don't have enough "urban" to worry about.

"You fly over Tallahassee and what do you see? Trees. This is not a big paved-over city," said Goree, warning-coordination meteorologist with the National Weather Service in Tallahassee. "My gut reaction, without any quantifying, is any urban heat factor in Tallahassee would be negligible."

Goree said our recent near-daily rains have been part of a broad movement of storms from west to east meeting a cool low-pressure area over the eastern U.S. The rain also has been a product of warm moisture-laden sea breezes from the Gulf of Mexico moving inland. When warm moist air meets cooler air, it rises, condenses and rains. When it rises very high, it forms ice crystals, which collide, creating static electricity and — voila! — lightning and thunder. But where the rain falls is random.

"The nature of thunderstorms is they are little pocket cells of energy and they produce localized rain," Goree said. "Heavy in one small area and lighter or nil in others."

A common complaint is that Tallahassee's "official" rainfall never seems to match what any of us observed — unless we live near the airport. That's where Tallahassee's official rain gauge has been since 1961. The rain gauge is at the airport because serving aviation is part of the Weather Service mission. And having it in the same place for decades provides consistency for scientific

APPENDIX B: CONTROL GROUP TASK
Lab 7 News Article Exercise (10 minutes)

Please read the following news article about actual and official rainfall measurements and answer the questions at the end. You have 10 minutes to complete this exercise.

It never rains at Tallahassee's airport (and other weather myths)
By Gerald Ensley
comparisons. Still, it's commonly believed the official rainfall tallies are at odds with reality — because we each have our own reality.

"I suspect if you could magically produce a map of hundreds of years of rainfall data, which showed rainfall distribution (in Tallahassee), it would be pretty homogenous," said Goree. "Of course, humans live in today, and if it didn't rain in my yard something is wrong."

Still, the differences in rainfall can be startling. In October, Florida became the 34th state to join the Community Collaborative Rain, Hail and Snow Network. CoCoRaHS (pronounced ko-ko-rahz) asks average residents to measure rainfall at their homes (using approved equipment) and report daily precipitation amounts (online). Leon County has 30 observers so far. On June 25, several observers reported less than an inch of rain — while others recorded more than 6.5 inches. Officially, 3.1 inches of rain fell at the airport. Yet CoCoRaHS is about confirming rainfall rather than proving differences. It was founded in 1998, after 14 inches of rain fell near Fort Collins, Colo. — while only 2 inches fell at the city's NWS station — and caused flash flooding that did millions in damage. Now, the NWS uses CoCoRaHS readings in making its flood warnings; other agencies use them for water and drought tables.

"This helps fill in the gaps and actually see where it's raining," said Melissa Griffin, assistant state climatologist. "(But) precipitation is highly variable. You can't use (CoCoRaHS) to prove it rains more on one side of town than the other."

Tallahassee Democrat ©2008
(Ensley, 2008)
Now, please answer the following questions:

Why do rainstorms typically move from West to East across Tallahassee?

Why is collecting actual rainfall amounts from different locations better than relying on the official rainfall recorded at the Tallahassee Airport?
Biologists find some animals get early warnings on natural disasters
By David Fleshler

As hurricane after hurricane struck Florida last year, animals showed a striking ability to predict catastrophe and get out of the way. When Hurricane Charley came within hours of the Caloosahatchee River, eight sharks tagged by biologists suddenly bolted out of the estuary to the safety of the open ocean.

When Hurricane Jeanne approached Gainesville, butterflies in an experimental rain forest wedged themselves under rocks and disappeared into tree hollows. And as the whole series of hurricanes churned through the state, birds appeared to delay their migration south, stacking up somewhere north of Florida until the route to their winter habitat was safe.

Like the elephants, buffalo and deer of South Asia that fled to high ground well ahead of last month's tsunami, many Florida animals have shown they can predict hurricanes and take steps to survive them.

While there was talk that the Asian wildlife displayed a "sixth sense" in anticipating the huge waves, scientists say animals may simply have a more acute ability to detect vibrations, smells or changes in barometric pressure. Until the past few decades, when humans invented weather satellites and seismographs to extend the range of their own crude sensory organs, it may be that animals had the advantage in avoiding natural disasters.

"It doesn't make any difference if it's a hurricane, a fire or an earthquake," said Frank Mazzotti, a wildlife biologist at the University of Florida. "They apparently sense these things before humans can do that. Not a lot of work has been done to learn the sensory mechanisms. It's likely a combination of smell, vibrations, and pressure. They start moving away from danger before humans pick it up."

Hurricane Jeanne was several hours away from Gainesville last September when University of Florida biologist Thomas Emmel noticed butterflies taking shelter among rocks and trees in the university's enclosed rain forest. He suspects they could detect changes in barometric pressure with eardrum-like organs on their abdomens. Because air pressure decreases before a storm, this ability allows them to avoid being torn apart by high winds.

About 12 hours before Hurricane Charley struck southwestern Florida, scientists at Mote Marine Laboratory noticed odd behavior among sharks they had tagged in Pine Island Sound. As underwater hydrophones listened, eight of the 10 sharks headed swiftly out to sea. Michelle Heupel, staff scientist at the lab's Center for Shark Research, said she suspects the sharks sensed the drop in air pressure and instinctively headed for the safety of the open ocean.
"If they get caught in the storm surge or big wave action, they could get bashed around or pushed ashore," she said. "What we've been finding fairly consistently, that sharks in coastal areas actually leave the area as storms approach."

While sharks fled the area, migratory birds may have delayed their flight through Florida until the hurricanes passed. Fred Griffin, a Broward County birder, said it appeared that birds waited until October, very late in the season to head south into Florida.

"Once the hurricanes got through, it seemed like the migration really started," he said. "You have to figure they were hanging around and waiting for the atmosphere to clear out."

Douglas Levey, professor of zoology at the University of Florida, said birds have the ability to time migrations to take advantage of trailing winds and avoid headwinds. As with other animals, he suspects it's through detecting changes in air pressure. "Nobody is out studying birds during a hurricane," he said. "But we can tell you that a lot of birds survive. Nobody has ever been able to tell where they go during a hurricane. But it's safe to say most of them find shelter."

The hurricanes of 2004 avoided the southeastern tip of Florida, home to endangered American crocodiles. But judging from past experience, the reptiles would have known how to handle whatever nature threw at them. In 1992 Hurricane Andrew scored a direct hit on the crocodiles that live in the cooling canals of the Turkey Point power plant in southern Miami-Dade County. But when the storm passed, not a single dead crocodile was found. No one knows where they went, whether to open water or the bottom of 20-foot canals.

"There was no diminishment of nesting activity," Mazzotti said.

Not all animals could avoid danger. Last year's hurricanes wiped out about half the sea turtles nests in Florida, washing them away or burying them in sand. Many bald eagles returned to the state this winter to discover their nests were destroyed. After one of the hurricanes that passed over Lake Okeechobee, 30 to 40 dead alligators were found along the northwestern shore, Mazzotti said.

Among experienced hunters and fishermen, it's well known that animals show themselves more in the days or hours before a hurricane, as they pack in calories before the storm makes it hard to find food.

"When you go fishing before a storm, they bite like crazy," said Bouncer Smith, a Miami Beach charter captain. "Snook, grouper and tarpon feed very aggressively because storms cause them to relocate and make the water dirty."

"It was like somebody rang the dinner bell."

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Now, please answer the following questions:

What are some scientific explanations for why animals may be able to predict storms and other natural disasters with such certainty?

What are some other “myths” for predicting storms and other natural disasters that you might be familiar with? (discuss these other myths from a scientific perspective)
Weather Forecasting: Myth or Reality
Is it Possible to Accurately Forecast the Weather Months in Advance?
By IA ROBINSON

June 30, 2008—

Humans have always wanted to predict the future. Never has this been truer than when it comes to the weather. For years, meteorologists have given five-day forecasts and precise hour-by-hour predictions, but imagine if you could give a 360-day forecast. Though most experts say it's nearly impossible to predict anything yearly as accurately as you can from day to day, don't tell that to farmer Jack Ponticelli.

Ponticelli and his son Aron are proud owners of the Piedmont Truffle Farm in North Carolina. They expect multimillion-dollar returns this year and happily give some credit to "The Old Farmer's Almanac."
"We use the almanac to help us schedule our workers, to schedule planting, and for general weather patterns over the year, for our irrigation system and also for fuel budgeting," explained Ponticelli.

Dartboard Science
For 216 years, "The Old Farmer's Almanac" has given its day to day predictions – 18 months in advance – on everything from scattered thunderstorms to sunshine. For Ponticelli, the almanac is a tool that he believes few farmers will be quick to abandon.

"As science becomes more advanced, they may not use the almanac as much as they used to in the past but they'll still rely on the almanac," he said. "Farmers are very traditional people and they tend to use things that they know and understand."

But not everyone trusts the almanac's information. Paul Knight teaches a class on long-range meteorology at Pennsylvania State University, and, like many in his field, he regards the almanac as "dartboard science."

"I think it's difficult to buy any science that is not explaining how they do their work. So, certainly anybody can say anything they want about what it'll be like a year from now, but if you want to claim any credibility in the scientific sense, and also be able to have people buy into what you're forecasting, you have to show your technique," Knight said.
Regardless of the controversy surrounding the science behind the almanac, nearly all meteorologists agree that forecasting long range, or any time frame further than 10 days ahead, is possible. The difficult part is getting the forecasts correct. Knight explained the different criteria between long-range and short-range forecasts: "The information that's available in a longer term is much more of the trend variety, so ... the temperatures will average above or below normal, or a heat wave or a cold wave. It's nothing specific, as in short-range."

**Predicting Weather for Big Name Corporations**

Yet, giving specifics is exactly what a handful of meteorologists are daring to do by predicting next year's weather right now. For Bill Kirk, CEO of Weather Trends International, forecasting general weather trends a year from now is only the beginning. His predictions already include daily temperatures, weekly amounts of rain and monthly amounts of snow one year from now.

His clientele list reads like a who's who of name brand products. "We work with huge corporations: Wal-Mart, Khol's, Anheiser Busch, Duraflame, I mean these are huge corporations that, for six years ... for the fees we charge if we were wrong, they wouldn't subscribe next year," he said.

Kirk is quick to defend the data and techniques behind his company's results. "Traditional meteorology, as you know, does not work beyond 14 days. You cannot use that to project next year's weather. So, we have a proprietary process...[that includes] statistics, math, climate [a] secret formula, if you will, that projects these trends."

But why would companies selling beer, first aid or even orange juice be so concerned about weather in the first place? Kirk said that what's happening outside affects when and how much we dig into our wallets.

"We consume more orange juice – 60,000 more bottles of orange juice – for every one degree colder it is nationally," he said. "So, this week, here, is 13 degrees colder than it was a year ago. We're talking about hundreds of thousands, if not millions of boxes of orange juice that are being sold because of weather."

Kirk firmly believes the uses of long-range prediction will only gain in popularity. "I think this will change the world. We are talking to the travel sites and Googles of the world – imagine you getting the same value as my large national retailer that spends a lot of money for this service, so you can plan your vacations, your golfing trips, with a little bit more degree of skill. Get the wedding in a more likely period to have the weather that you want."

"So, you can do that, maybe it's not eight times out of 10 when you're speaking about a real finite period of time, maybe it's six or seven times out of 10, but it's still better than guessing or waiting to see what happens."

Despite those meteorologists on the cutting edge of business-meets-weather, most conventional experts in the field still contend that the science on long-range meteorology will never get as precise as a five-day forecast. They argue true accuracy is too uncertain, especially for events, such as hurricanes, which profoundly affect weather results. Unfortunately, it's not possible to know if it will rain on that fishing trip you have planned for 2009. As Knight asserts, "It's smart to use climatology for business decisions, but as far as the type of info that has a climatic theme to it – that is, it tells you normal conditions in the various
parts of the country that you're interested in marketing too – that's smart. [But] to believe that specific events are going to happen is stupid."

This report first aired on April 16, 2008.
Copyright © 2008 ABC News Internet Ventures
(Robinson, 2008)
Now, please answer to the following questions:

What are some reasons why long-term weather prediction might be important?

Why do you think people drink more orange juice when the weather gets colder?
1. **Objective**

The objective of this lab is to learn and understand what factors are needed for hurricane development, what causes them to intensify or weaken, what steers them, and what kinds of impacts are caused. We use the 2004 Atlantic Hurricane Season as our guide since this season was exceptional in so many ways, not the least of which was the direct impact of four significant hurricanes on the State of Florida in one year.

In this lab we will focus not only on how hurricanes are tracked, but also how scientists obtain quantitative information about them through satellite, radar, and reconnaissance aircraft information. Further, we will examine the effect of uncertainty on forecast products, and the public's response to them. You will gather data to develop some sense for scientific research and how scientists might draw conclusions from such activities. Finally, we will examine the effect of storm size on the effects that a coastal region may anticipate.

2. **Introduction**

Each summer and fall, the Atlantic Ocean hosts a number of weak tropical low pressure systems called *tropical waves*, which carry showers and breezy conditions. Sometimes, these storms organize into a *tropical disturbance*, which is a small cluster of thunderstorms. If this disturbance finds its way over warm water and in a weak *wind shear* environment, it may organize into a *tropical depression* (with winds of at least 20 mph and a low level counterclockwise circulation), a *tropical storm* (with winds of 39 mph or greater, at which point it is named), or a *hurricane*.

A hurricane is an intense tropical cyclone, a warm core system, with sustained winds of at least 65 knots (1 knot = 1 nautical mile per hour = 1.15 mile per hour), or 74 mph (119 km/hr) or higher. Most hurricanes develop in the late summer, between the latitudes of 5°-20°, and where the water is at 26.5°C (80°F) or higher. Hurricanes may also form from stalled frontal systems or other surface low pressure areas.

3. **Characteristics and Life Cycles of Tropical Cyclones**

- Hurricane Season in the North Atlantic Ocean (and Gulf of Mexico and Caribbean Sea) is 1 June through 30 November each year; in the East Pacific Ocean, the season begins in mid-May.
- Tropical cyclones (called hurricanes in the North Atlantic and East Pacific, and typhoons, cyclones, and other regional names elsewhere) fuel themselves with the release of latent heat.
- A tropical depression is numbered and tracked when winds first reach 20 kt and there is a closed low pressure circulation; winds may reach 33 kt (36 mph).
- A tropical storm is given a name when the winds increase to between 34 and 63 kt (37-74 mph) - the list of names currently used is shown in Table 7-2.
- Hurricanes will generally weaken when they make landfall, move over cool waters, or into areas of strong wind shear.
• A weakening tropical cyclone may become a depression again after it loses strength; it will retain its name rather than have its number restored.
• The eye of the mature hurricane has clear skies and descending air and the eye wall has the most intense winds and heaviest rain.

The Saffir-Simpson scale (Table 7-1) is used to classify the strength of hurricanes.

**Table 7-1: The Saffir-Simpson Scale of Hurricane Intensity**
(from NOAA, National Hurricane Center, http://www.nhc.noaa.gov/).

<table>
<thead>
<tr>
<th>Category</th>
<th>Maximum Winds</th>
<th>Central Pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>knots</td>
<td>miles per hour</td>
</tr>
<tr>
<td>1</td>
<td>65-82 kt</td>
<td>74-95 mph</td>
</tr>
<tr>
<td>2</td>
<td>83-95 kt</td>
<td>96-110 mph</td>
</tr>
<tr>
<td>3</td>
<td>96-113 kt</td>
<td>111-130 mph</td>
</tr>
<tr>
<td>4</td>
<td>114-135 kt</td>
<td>131-155 mph</td>
</tr>
<tr>
<td>5</td>
<td>&gt;135 kt</td>
<td>&gt;155 mph</td>
</tr>
</tbody>
</table>

Note: Some presentations of the Saffir-Simpson scale also include estimates of storm surge. We choose not to include them here, as storm surge varies according to numerous factors, with storm intensity being only one of them.

**Table 7-2: Names for North Atlantic Tropical Cyclones, 2008-2013**

<table>
<thead>
<tr>
<th>2008</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
</tr>
</thead>
<tbody>
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<td>Alex</td>
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<td>Andrea</td>
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<tr>
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<td>Florence</td>
<td>Fernand</td>
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<tr>
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<td>Grace</td>
<td>Gaston</td>
<td>Gert</td>
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<td>Hermine</td>
<td>Harvey</td>
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<tr>
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<td>Igor</td>
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<td>Mindy</td>
<td>Matthew</td>
<td>Maria</td>
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<td>Valerie</td>
<td>Van</td>
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<td>Walter</td>
<td>Whitney</td>
<td>William</td>
<td>Wendy</td>
</tr>
</tbody>
</table>

Beginning in the 1950s, storms were given names to allow them to be distinguished from one
another. Names are retired (after international consultation) if they are particularly associated with very damaging, destructive, or lethal storms. The storm names for the 2008-2013 seasons are given in Table 7-2.

4. **Hurricanes and Their Impacts**

Numerous hazards are associated with the hurricane. (Fatalities can occur due to weak tropical storms, and even a very strong hurricane may not yield a single human life lost.) Preparedness is the key to survival. Emergency management personnel are involved everyday in disaster preparedness or *mitigation*, which is an activity designed to minimize the impacts of a potential disaster.

- Storm surge is the increase in sea level associated with the front part and center of the hurricane; for most major storms, it may bring the most hazards and cause the most destruction, injury, and loss of life, particularly in coastal regions
- Winds for any hurricane (even category 1) may cause significant damage and cause loose objects or debris to become missiles which are hazardous
- Flooding is a serious hazard with most storms, even weaker tropical storms, which may dump copious amounts of precipitation at the coast and inland; flash flooding in more mountainous areas may also be a serious hazard
- Emergency management personnel will generally issue evacuation recommendations or mandates that should be heeded by the general public

5. **Hurricane Tracking**

All storms are plotted by hand or using interactive hurricane tracking maps. Generally, the latitude and longitude of each storm is available, and time/date and intensity information (wind speed and/or minimum central pressure) is plotted. Use the model below for plotting your storm locations. Different models may be used by different plotting programs.

You will plot one storm by hand, to reinforce latitude/longitude concepts, and calculate speed of forward motion of the storm. Mostly, however, we will use an interactive online java application to do our plotting for us. Most hurricane tracking maps are designed using the Mercator map projection, which you used in Lab #1. In this projection, all latitude and longitude lines are straight and it becomes quite simple to ascertain direction of a storm's movement, and speed, using a degree of latitude scale for distance.

Note that when you use a map such as we have introduced here for hurricane tracking, there often will not be a distance scale present. You may use the following for distance scales anywhere on this map:

\[ 10^\circ \text{ of latitude change} = 1,111 \text{ km or } 1^\circ \text{ of latitude change} = 111 \text{ km} \]

On your tracking map, each degree of latitude change corresponds to 111 km. You may use this as a distance scale to make up your own map scale (e.g., 111 km = ____ cm), as you did in Lab #1. In this exercise, care must be given to apply this locally since we are using a
Mercator projection. In other words, this distance scale will be accurate only in the 10 to 20 degree "belt" of latitude in which you made the scale (since latitude lines stretch out towards the Poles on this map projection).

We will also ask you to take data from official NHC advisories for Hurricanes Charley, Frances, Ivan, and Jeanne and plot the radius of tropical storm force and hurricane force winds for two of these storms at one time each before landfall (superimposed on the same tracking map you use for Charley). You will draw circular to elliptical areas indicating the radius of storm force (34 kt) and hurricane force (65 kt) winds, in different colors and shading, to indicate the threat for coastal residents. This will help us to determine the effect of storm size on the warned area. A sample plot map is found in Figure 7-2.

Although hurricane season runs through the summer and fall each year, spring is a good time to get prepared for the upcoming season, so this lab should be done regardless of the time of year!

![Figure 7-1: Plot of a hurricane track for a storm in the Atlantic Ocean. The storm starts at tropical depression intensity (25 kt) on the 1st of the month at 03 UTC (on the right, or east side of the map); its next position at approximately 16.5°N and 45.5°W illustrates a slight increase in speed to 30 kt. By 03 UTC on the 2nd, it is a tropical storm (hollow symbol), and it becomes a hurricane (filled in symbol) by 15 UTC on the 2nd. Note the storm motion from east to west (from right to left).](image-url)
FIGURE 7-2: Hurricane tracking map showing a plot of a hurricane at latitude 32.5°N, 69.5°W, with tropical storm force winds area shaded in light gray and hurricane force wind area shaded in dark gray. The spokes show the direction along which hurricane and storm force winds are measured from the center of the storm out to the NE, SE, SW, and NW, respectively (the same order in which this information is given in NHC advisories). These diagonals should not appear on your final map! The distances used are given on the exercise sheet, where a larger form of this map appears.

6. **Online Tropical Weather Information Sources**

There are many useful sites for tropical weather information and updates that are helpful that you may wish to “bookmark” for Internet browsing (and you will find them linked on the class home page for this lab; these are certainly not exhaustive given the proliferation of such sites on the Internet in recent years). We highlight a few here because we have found them to be particularly useful in a laboratory setting:

EXPLORES! and FSU Meteorology tropical weather (real-time) information center is at:
http://www.met.fsu.edu/explores/tropical.html

Unisys Corporation’s site for the 2004 season at:

The Weather Underground 2004 Atlantic Basin Hurricane Archive

The National Hurricane Center (NHC)
http://www.nhc.noaa.gov/
7. **Disaster Preparedness**

Time and time again it has been demonstrated that a community's preparation for a potential natural disaster can determine its ability to withstand such an event. In many communities in "tornado alley" air raid sirens have been converted to tornado sirens, which sound whenever tornado warnings are issued by the National Weather Service. In particular, the following "products" are routinely produced:

- The NOAA National Hurricane Center (NHC) in Miami issues all watches and warnings
- **Hurricane Watch**: a hurricane poses a threat to the area within 36 hours
- **Hurricane Warning**: hurricane type conditions will be felt within 24 hours
- Tropical Storm Watches and Warnings, and Inland Watches and Warnings (for non-coastal counties) can also be issued; local NWS offices will also issue Hurricane Local Statements designed to inform citizens in their area of responsibility.

In this instance, local and state emergency management officials work closely with operational meteorologists. The same type of approach is applied to areas affected by earthquakes, tsunamis, volcanoes, and hurricanes, among other hazards. Loss of life may still occur, but in general it is much less than if a disaster plan were not in place. For "hurricane alley" it is important not only for communities (collectively) to be prepared, but it is also important for individuals and families to be prepared.

Among the recommendations of the National Weather Service, Federal Emergency Management Agency (FEMA) and the American Red Cross are the following:
obtain proper insurance to protect your belongings and property and bring policy information with you or keep it safe
prepare a disaster supply kit in case you will "shelter in place" (at your home), with flashlights, batteries, radios (including a NOAA Weather Radio), battery-operated television, water, canned food
have cash on hand and fuel in your vehicles
do your laundry!
heed orders of local emergency management officials during time of evacuation and after the storm event; do not return to an area until it is officially deemed safe to do so
take responsibility for the elderly, infirmed, and pets in your care to make sure that they are safe
take action early in the event - know what you are going to do before a disaster strikes
if you will evacuate, know where you are going and notify at least one other person (who is not subject to evacuation or storm conditions) where you are going
bring only essentials with you when you evacuate

This lab will help you to determine your own attitude and readiness for a hurricane disaster in an online simulation game, Hurricane Strike!. But first we will ask you to plot one hurricane and then examine the potential impacts of storm sizes and track forecasts on a region. We will compare these storms to some from the other most recent active year in Florida, 1995 (which was the second most active year on record in the Atlantic), using on online hurricane tracking program.

At FSU, the first StormReady (a National Weather Service campaign to increase awareness of hazardous weather, and to mitigate some of its potential impacts) campus among public higher educational institutions in Florida, the community is kept aware via the main campus web site at http://www.fsu.edu/alerts/, through a siren system, as well as emergency text messaging and email delivery.

8. LAB INSTRUCTIONS

Some background preparation would be appropriate here if you feel you do not know anything about hurricanes, so we recommend your Meteorology textbook for lecture class or the online guide from WW2010 (online reference provided previously). In addition, we ask you to help prepare yourself by running the Hurricane Strike! scenario (from the online reference provided), before lab, if possible.

We will be tracking some notable storms form Florida from 2004 (already a very notable season of record among all the recorded hurricane seasons for which we have data, since 1851). You will use pages A7-1 through A7-4 for this lab, and you will also find a large hurricane tracking map (11" × 17") useful. We will ask you to plot two points per day for Hurricane Charley, the first major storm to affect land in 2004. The primary plot times are 03 and 15 UTC, but all advisory plots are listed for the sake of completeness. Plot according to the instructions shown for Figure 7-1, and answer all questions and complete all activities indicated on these exercise sheets. Follow all instructions on the instruction sheets and those given to you by your instructor.
THIS PAGE PURPOSELY LEFT BLANK.
1. [1] _______ The Hurricane Strike! online quiz must be completed by the deadline set by your instructor to receive points for this item. Follow instructions provided to you by your instructor by email or in class. All group members must complete the quiz by the deadline for the group to earn this point. It is important to spend some time on this particular program on your own (or in your group if you have time and flexibility of scheduling!) before you take the quiz!

2. [0.5] _______ Plot the track for Hurricane Charley on the large tracking map you are given, as shown in the Lab instructions. All points are listed for the sake of completeness, but please plot only the 03 Z and 15 Z observations, until 13 August, then plot all available observations. (e.g., the ones to plot appear in bold-italics)

<table>
<thead>
<tr>
<th>Time</th>
<th>Lat</th>
<th>Lon</th>
<th>Wind (mph)</th>
<th>Pressure</th>
<th>Storm type</th>
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<tr>
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<td>74.7W</td>
<td>65</td>
<td>999</td>
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</tr>
<tr>
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<td>76.1W</td>
<td>70</td>
<td>996</td>
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<tr>
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<td>77.5W</td>
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<td>993</td>
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</tr>
<tr>
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<td>78.7W</td>
<td>75</td>
<td>993</td>
<td>Category 1 Hurricane</td>
</tr>
<tr>
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<td>79.9W</td>
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<td>986</td>
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</tr>
<tr>
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<td>81.2W</td>
<td>90</td>
<td>983</td>
<td>Category 1 Hurricane</td>
</tr>
<tr>
<td>21 GMT 08/12/04</td>
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<td>81.9W</td>
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<td>980</td>
<td>Category 2 Hurricane</td>
</tr>
<tr>
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<td>82.4W</td>
<td>105</td>
<td>975</td>
<td>Category 2 Hurricane</td>
</tr>
<tr>
<td>09 GMT 08/13/04</td>
<td>23.9N</td>
<td>82.9W</td>
<td>110</td>
<td>970</td>
<td>Category 2 Hurricane</td>
</tr>
<tr>
<td>15 GMT 08/13/04</td>
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<td>82.8W</td>
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<td>965</td>
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</tr>
<tr>
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<tr>
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</tr>
<tr>
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</tr>
<tr>
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<td>79.0W</td>
<td>75</td>
<td>990</td>
<td>Category 1 Hurricane</td>
</tr>
</tbody>
</table>

... some points not included here (off chart) ...

a. [2] _______ Using the information from the Advisories for Hurricane Charley and Frances, plot the size of the storms, using the information in the lab instructions for Figure 7-2. Use different colors for each storm, please! We have taken the liberty of converting the official advisory values that were given in nautical miles to kilometers.
Hurricane Charley Forecast/Advisory Number 17…Corrected

NWS TPC/NATIONAL HURRICANE CENTER MIAMI FL AL032004
1500Z FRI AUG 13 2004

HURRICANE CENTER LOCATED NEAR 25.2N 82.8W AT 13/1500Z
POSITION ACCURATE WITHIN 15 NM

PRESENT MOVEMENT TOWARD THE NORTH OR 360 DEGREES AT 16 KT (30 km/hr)

ESTIMATED MINIMUM CENTRAL PRESSURE 965 MB
EYE DIAMETER 19 KM
MAX SUSTAINED WINDS 95 KT WITH GUSTS TO 115 KT.
64 KT……. 46NE 46SE 28SW 28NW.
34 KT……. 167NE 167SE 139SW 139NW.

WINDS AND SEAS VARY GREATLY IN EACH QUADRANT. RADII IN KILOMETERS
ARE THE LARGEST RADII EXPECTED ANYWHERE IN THAT QUADRANT.

Hurricane Frances Forecast/Advisory Number 36

NWS TPC/NATIONAL HURRICANE CENTER MIAMI FL AL062004
2100Z THU SEP 02 2004

HURRICANE CENTER LOCATED NEAR 24.1N 74.8W AT 02/2100Z
POSITION ACCURATE WITHIN 15 NM

PRESENT MOVEMENT TOWARD THE NORTHWEST OR 310 DEGREES AT 9 KT (17 km/hr)

ESTIMATED MINIMUM CENTRAL PRESSURE 948 MB
EYE DIAMETER 46 KM
MAX SUSTAINED WINDS 120 KT WITH GUSTS TO 145 KT.
64 KT……. 130NE 93SE 56SW 111NW.
34 KT……. 296NE 241SE 167SW 222NW.

WINDS AND SEAS VARY GREATLY IN EACH QUADRANT. RADII IN KILOMETERS
ARE THE LARGEST RADII EXPECTED ANYWHERE IN THAT QUADRANT.

(We have omitted some text and also radius of maximum 50 kt winds and 12 ft seas; these are of course hazards, too - if you are interested in the full bulletins, they can be accessed online at the National Hurricane Center archive page at http://www.nhc.noaa.gov/archive/2004/index.shtml.)

b. [0.5] _______ We want you to assess the relative threats of the two storms, Charley and Frances, to the coast. Based upon their present speed of motion shown in the advisory above (we have listed the speeds in km/hr, too) and direction, when and where do you anticipate Florida landfall [do not use your post-event knowledge of the events here, please!]? Sketch in likely areas to affect tropical storm force winds for these two storms, based upon the forecast track.

In the example shown in Figure 7.2 in the lab instructions, the following storm radii were used:

64 KT……. 66 NE 66 SE 44 SW 33 NW
34 KT……. 165 NE 176 SE 121 SW 132 NW
How good are your forecasts for Charley and Frances, compared to what actually happened? What evidence did you use to validate them? You may use one of the posted online hurricane tracking programs, if you wish.

3. [3] ________ Each group will be assigned a new hurricane to examine (on a card). Each member of your group will have one of the following roles:

- **meteorologist** - defines the threat area from storm winds and potential storm surge
- **emergency management specialist** - defines areas which are likely to need evacuation
- **coordinator** - coordinates efforts between teams and keeps them on task, on time; public affairs
- **warning event specialist** - defines timing and location of watches and warnings* (*in groups of 3, do not assign this job, it will be shared)

Each person is responsible for preparing their team for a briefing which will be conducted approximately 35 minutes from the time the assignment is given. Specifically, the following information will be reported by the coordinator:

- The location and intensity of the storm
- The size of the storm
- The likely path for the storm
- The watches and warnings issued and about to be issued
- Other general actions necessary for public safety

For the remainder of this lab, questions 6-9 can probably not be accomplished in the available time allotted for lab. It is suggested that each group member be assigned part of the remaining work to complete, and then be prepared to share the results of their work within their group at the start of the next class. Your instructor will provide instructions indicating the amount of time permitted to work on assembling the lab packet to be turned in by your group (it should include all plotting maps completed for #2, #3, and #5.

4. [1] ________ The British Meteorological Office site has over ten years of online monthly summaries for tropical cyclone activity. Globally, which ocean basin is the most active and which one is the least active (for the data available on the WWW site)? In order to answer this question, you may wish to make a data table listing the number of tropical storms (or stronger) for each basin. Does this result surprise you? **See** the lab instructions for the web site to peruse for the required information.
In the very busy year of 1995, hurricane forecasters and the general public were kept very busy. In particular, two storms affected Florida significantly, Erin and Opal.

5. [0.5] _______ Look at Erin's track using the one of the online simulators. Why do you think that Erin weakened part way through her life cycle?

6. [0.5] _______ Look at Opal's track. From its leisurely days over the Bay of Campeche, it suddenly and unexpectedly accelerated and intensified, weakening again just before making landfall in the Florida panhandle. Do you think this had any affect on hurricane preparedness for residents there?

7. [1] _______ What appear (to you) to be the two most important issues or questions related to the public's preparedness for a major hurricane making landfall near their home?

10. [0] All group members please initial here to indicate that this work was carried out collaboratively with all members participating.

________________    ______________    ______________    ______________
Smaller maps follow - you should use the larger maps in Appendix B for your assigned work, however.
1. **OBJECTIVE**

This lab is designed to help you become more familiar with the phenomenon known as El Niño/Southern Oscillation (ENSO) and its impacts. The lab is designed to be fully participatory with group learning and lots of chance for discussion, so that you can learn first-hand about ENSO and its effects.

2. **INTRODUCTION TO EL NIÑO**

Every few years, the phenomenon known as El Niño occurs. At first glance a local phenomenon associated with warm water in the tropical eastern South Pacific Ocean (El Niño is known as the warm phase), the ENSO is a complex physical system involving interactions between the ocean and atmosphere on multi-year time scales, and large spatial scales. It poses both societal and economic impacts that affect the entire world. Its most familiar manifestation is the appearance of unusually warm water off the coast of Peru and Ecuador, which lasts for several months, spreading across the coastal eastern Pacific Ocean in the Northern and Southern Hemispheres.

The 1972/73 El Niño event sparked tremendous interest in monitoring programs for the tropical Pacific Ocean, in particular, and NOAA, as the lead agency involved in monitoring of the ocean and atmosphere, has played a lead role in funding investigations at research labs and Universities, including Florida State. Permanently mounted and free drifting buoys continuously monitor air and sea conditions to provide instantaneous measurements of the events associated with ENSO. Several significant El Niño (and its cool counterpart) have occurred since that time, with major consequences on agriculture, forestry, economy, weather, etc.

3. **LAB INSTRUCTIONS - GET READY, DO YOUR RESEARCH!**

Below you will find a number of questions that we will use to frame our discussion of ENSO's impacts. You will be given a fixed amount of time to work on these questions in small groups before we break out for large group discussion. We will begin by placing ourselves back in the Fall of 1997, which was the first year that any major research groups predicted would bring an El Niño months in advance. The public may have heard of El Niño before, since there had recently been some pretty strong events, with consequences across the world. Our local newspaper provided some interesting perspective:

1. Read the ENSO article from the *Tallahassee Democrat* (22 September 1997) on the last page of the lab to obtain some background information on El Niño. Summarize the forecasted effects of the 1997/1998 El Niño on the expected wildfire activity level across the State of Florida for that season, according to the article. Keep in mind you are back in Fall 1997!
2. In general, what are the expected effects of El Niño on Florida winter forest/brush fires, when such conditions exist (based on the article read for #1)? We next look for independent confirmation of hypotheses raised in the aforementioned article...please check the forest fire forecast for Florida (say that 3 times fast!) page from the Florida Department Agriculture and Consumer Services/Division of Forestry (DOF) www site at http://www.fl-dof.com/fire_weather/forecast/seasonal_forecast.html. What does the DOF expect in the way of fires for this season (you are back to the present now!)?

3. What is the opposite of El Niño called? [Note: El Niño is called the warm phase; we are looking for the name of the cold phase here.] What are its effects on hurricanes in the North Atlantic Ocean? Provide your source of information for this question (URL or WWW address, text reference, magazine, etc.; provide complete citation information!).

4. Read about the scientific method - a very good online source is available at http://en.wikipedia.org/wiki/Portal:Scientific_method. Keep these steps in mind when you respond to the next question.

5. On the FSU/COAPS ENSO Climate Effects page, http://www.coaps.fsu.edu/lib/booklet/, you will see a table of cold, neutral, and warm ENSO phase years (scroll down for the table). Pick 5 cold years, 5 neutral years, and 5 warm years. Discuss among your group how you will select your information. Now examine the number of named storms for the North Atlantic Ocean, using the Unisys corporation hurricane tracking archive that we used previously for the hurricane tracking lab, or another reference. Find the average number of named storms for each ENSO phase and see if your results agree with your answers to #3. (they may not! - please show all your work on the worksheet). Be prepared to discuss and demonstrate your results during class time!

6. What is the average period (in years) between El Niño years, for all years in the COAPS sample? Show your work!

7. What are some effects of ENSO on weather/climate in one other part of North America (other than Florida)? Provide source information. What are some effects of ENSO on weather/climate in one other part of the world? Provide source information.

8. Provide an example of the effects of ENSO on a type of biological species (Cambridge Scientific Abstracts site [http://www.csa.com/discoveryguides/prednino/overview.php], or you can choose your own, but make sure to provide source information!)

9. Find data that tell what the warmest water temperature in the eastern tropical Pacific Ocean is at present; provide your specific reference (either a URL address/WWW site, or other complete citation; check the ENSO links on the class home page for help here!). Sometimes these data are reported as an anomaly, which simply means departure from normal.
You may wish to read some about the lighter side of El Niño here, courtesy of columnist Dave Barry. His "The Sky is Falling" column may be found at http://yankee.met.fsu.edu/~ruscher/Met1010L/barry-elnino.html.

4. **HELPFUL LAB LINKS FOR THIS LAB**

What is El Niño? (NOAA)
El Niño Online Meteorology Guide (University of Illinois)
http://ww2010.atmos.uiuc.edu/(Gh)/guides/mtr/eln/home.rxml
Blank maps for the Pacific Ocean may be helpful - a good online site is
http://www.eduplace.com/ss/maps/
National Geographic Article on El Niño
http://www.nationalgeographic.com/elnino/mainpage.html
Science Friday links from spring 1998 and also from 2002 (the subsequent event)
NOAA research on El Niño from the National Weather Service Melbourne
http://www.srh.noaa.gov/mlb/enso/mlbnino.html

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**TALLAHASSEE DEMOCRAT**

**CALENDAR SAYS FALL, BUT DON'T BELIEVE IT**

*EL NIÑO SHOULD GIVE US A COOL, DAMP AUTUMN. REALLY. BUT NOT THIS WEEK.*

*Monday, September 22, 1997*

Page: 1A

**Pete Reinwald DEMOCRAT STAFF WRITER**

We need to revise the seasons - winter, spring, summer, bawl.

If you've been expecting a big break from the heat, you might feel like crying.

"I thought a cold front was supposed to be coming through," Tallahassee attorney John Cooper said Sunday to anybody who had the energy to listen during a break in the Tallahassee Soccer Association's fall adult league. "This is the El Niño version of a cold front, right?"

Right. But more on that later. Predictions last week of markedly cooler temperatures beginning today were, well, just a front, and a weak one at that.

So on the first day of fall, the heat remains a hassle. Only a slight drop in temperatures - a high in the low 90s and a low around 70 with a slight chance of rain - are expected today as autumn is bumped to the back burner.

Last week, The Weather Channel forecasted a high of 76 and a low of 60 for Tallahassee today. On Friday, its forecast was revised to a high in the low 80s and a low in the low 60s.

"It'll be a taste of fall for you," The Weather Channel senior meteorologist Tom Moore said Friday by telephone.

Fall schmall. Sunday set a record in Tallahassee, with a high of 99 degrees.

WTWC Channel 40's Mike Rucker has predicted that the cold front that brought snow to Montana would stall today just south of here, keeping the cooler temperatures north of Tallahassee.

A second front is expected to pass through late this week, keeping our highs in the mid to upper 80s and lows around 70 throughout the week.

It won't feel like fall - that's for sure. But look on the bright if not burned side: It could be in the upper 90s again.

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**LAB 8 – EL NIÑO/SOUTHERN OSCILLATION**

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``It sounds funny to 'cool off' to the upper 80s,'' Rucker said Sunday. ```But I think we will tell a difference.''

Looking ahead, Rucker said, ```we'll have those little up-and-down swings in the temperature for the next month or so.''

That brings us back to El Niño, the weather phenomenon that happens every three to five years and turns global weather patterns upside down - usually to North Florida's benefit.

El Niño (``The Child,'' for the Christ child, because Peruvians would notice its effects around Christmas) is a warming of waters off Peru that causes changes in upper-level winds. Those changes result in, among other problems, severe drought in Australia and Indonesia and violent rains and floods in Peru and California.

Climatologists say this could be the strongest El Niño in 150 years. They say it certainly will be the strongest since the one in 1982-83, which brought catastrophic damage throughout the world, including $1.1 billion in flooding to the Gulf region.

If history is any indication, Tallahassee can count on a wet and cool but not cold fall and winter. Noted El Niño expert Jim O'Brien of Florida State University's Center for Ocean-Atmospheric Prediction Studies said that we can expect an inch or two more of rain than usual from October through December.

``Not enough to be noticed by humans,'' he said, ```but our trees and plants will love it.''

The increased clouds will help keep the days relatively cool. The nights won't be as cold as in typical winters, because fewer fronts will make their way down.

``El Niño's a good dude for Florida, because by getting us this fall and winter extra rain, it kills forest fires,'' O'Brien said. ```El Niño is very disastrous. But for us, it's really quite a good event.''

State meteorologist Andy Devanas said, ```We're not anticipating any severe weather to come out of this.''

But The Weather Channel's Moore said that the Super Storm of '93, which brought 60 mph winds to Tallahassee and killed 10 people and destroyed 115 homes in Taylor County, came during an El Niño year. ```Some of these storms can be stronger in El Niño years, because they have more energy in them when they start out on the other side of the (Pacific) ocean,'' Moore said.

The eastern Pacific generally is not a place for storminess, because the water's too cold. But in El Niño years, the warming of the waters off South America causes instability in the atmosphere and a shift of the subtropical jet stream - a band of fast-moving air currents that meanders and shifts around the southern part of the Northern hemisphere.

The instability ignites storms, and those storms follow the flow of the jet stream into California, across the southern U.S., and then into the Gulf. There they can be re-energized by the warm water just in time to nail Florida.

In March 1993, a jet stream of arctic air dipped into Texas and collided with a low pressure system headed east along the southern jet stream. The collision of cold and warm air energized the low pressure system and touched off what some called the Storm of the Century.

Taylor County was among 36 Florida counties designated disaster areas.

``It was like a hurricane in March,'' said Rucker, who while at WCTV Channel 6 was credited with predicting the storm and alerting North Florida viewers to it. ```It was a very, very rare storm.''

It was rare because fewer blasts of cold air are produced during El Niño years.

``It won't mean that cold air won't come down,'' Moore said. ```But it won't come down as excessively.''

Of course, El Niño has kept hurricanes away, too - just as FSU professor Jim Elsner said it would. In December, Elsner predicted below-normal activity of six hurricanes, two of them major, for this Atlantic hurricane season. In El Niño years, winds blow in a direction not conducive to hurricane development in the Atlantic.

More than halfway through hurricane season, which goes through November, we have had three hurricanes, one major. Elsner updated his prediction in August to a total of five hurricanes, two major.

``It is likely that we will see at least one more storm,'' Elsner said. ```It might even be a strong storm.''

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Each group should turn in only one page A8-1 for this lab. Each individual should turn in their own page A8-2 for individual grading! Work together as a group on this page as time allows.

2. [1] _______ In general, what are the expected effects of El Niño on Florida winter forest/brush fires? What does the DOF expect in the way of fires for this season (you are back to the present now!)

3. [1] _______ What is the opposite of El Niño called? ________________________
   What are its effects on hurricanes in the North Atlantic Ocean?

Source(s): ________________________________

5. [4] _______ Pick 5 years each category - and list number of named storms

<table>
<thead>
<tr>
<th>Year</th>
<th>Number</th>
</tr>
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Average Number: ________________________

<table>
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<th>Year</th>
<th>Number</th>
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Average Number: ________________________

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</tbody>
</table>

Average Number: ________________________

How scientific was your experiment? ________________________________

Does it match the hypothesis you came up with in #3? ________________________________
6. [1] _______ What is the average "return period" of El Niño in years? Show your work and answer to the nearest tenth, please!

__________ years

7. [1] _______ (a) What are some effects of ENSO on weather/climate in one other part of North America (other than Florida)? Provide source information. (b) What are some effects of ENSO on weather/climate in one other part of the world? Provide source information.

8. [1] _______ Provide an example of the effects of ENSO on a type of biological species (the Cambridge Scientific Abstracts site, or you can choose your own, but make sure to provide source information!)

9. [1] _______ Find data that tell what the warmest water temperature in the eastern tropical Pacific Ocean is at the present time; provide your specific reference (either a URL address/WWW site, or other complete citation; check the ENSO links on the class home page for help here!). What phase of ENSO is occurring right now? For possible bonus credit, can you tell if the source of the data you find is from a buoy, ship, or satellite (or other) observation platform?

ENSO Phase: ____________________________ Water Temperature: __________

Source: ________________________________

Bonus: ____________________________ Name ________________________________

please turn in your own sheet for this page only!

A8-2
1. **Objective**

The objective of this lab is to learn about the instruments used to take upper air observations and how to make some upper air calculations. We will also demonstrate the determination of the heights of standard pressure surfaces from radiosonde observations of pressure and temperature, and the use of wind-drifted balloons to take lower level wind observations using a pilot balloon, or *pibal*.

2. **Introduction**

Surface observations using the standard instruments discussed previously are easily and (relatively) inexpensive accomplished. Sampling temperature, pressure, moisture, and winds at elevation is important, as well. It is also more difficult and expensive.

Early *in situ* efforts ranged from instrument-bearing kites to manned balloon ascents. Tethered balloons filled the need for observational time series at a fixed, low level. The upper atmosphere was sampled directly by rocket and indirectly by inferences from meteoroid trails. Satellites now provide more complete indirect sampling coverage. Their estimates are less precise than direct probing, but they do afford a dense, worldwide operational coverage. A radar-based, indirect observational tool, the wind profiler network, has been added recently.

The observational mainstay for decades has been the free balloon. In its simplest form, the pilot balloon observation (PIBAL) – a small, 30-gram balloon filled with helium (figure 9-1) – is released, timed and followed with an angle-tracking instrument, the theodolite. The balloon is given a defined buoyancy or lift, and the presumption is that the rate-of-ascent is known. Given the height and the vertical and azimuthal angles, minute-by-minute horizontal displacements can be estimated and used to infer the average wind velocity in layers defined by the one-minute averaging interval.

The *radiosonde*, introduced by Russian geophysicist Pavel Molchanov (1893-1941) in the 1920’s, became the worldwide operational standard for pressure-temperature-moisture profiles (figure 9-2). An instrument package is carried aloft by a 500- to 1,500-gram balloon, sometimes to an altitude as high as 30-40 km. As the balloon rises, an aneroid cell varies the setting on a *baroswitch* (pressure instrument). Temperature is measured with a thermistor (a small electrical resistance thermometer), and moisture is found with a carbon-coated plate or a hygristor, or with more modern composite materials that provide similar or greater sensitivity. The signal from an attached radio transmitter is modulated sequentially by the baroswitch and reflects the signal levels produced by the sensors. A ground-based receiver processes and interprets the signal. Many receivers now use modern GPS technology to provide very high accuracy as to instrument position throughout its flight.
3. **THE PIBAL**

Historically, the pibal has been used to document the wind structure in the lowest 6 km of the atmosphere (or so). In order to obtain useful meteorological data from a pibal observation, we must assume that the released balloon will move according to the winds encountered as it moves aloft. In order to determine the winds, the balloon's position is tracked using an instrument called a *teodolite* (Figure 9-3).

**Figure 9-3:** Theodolite for recording of azimuth and elevation angle of pilot balloon.

**Figure 9-1:** A pilot balloon, used for determination of upper level winds in the lower troposphere. The counterweight is used to assure neutrally buoyant conditions at sea level. The upward directed force is the free lift, and the downward directed drag force, producing a nearly constant ascent rate over time, balances this.

**Figure 9-2:** The radiosonde.
The balloon will rise at nearly a fixed ascent rate depending on the mass of gas in the balloon and balloon itself. For the 30 gm balloons we will use in our class, the ascent rate is a nearly constant 590 ft/min in relatively still air (180 m/min; except in the first five minutes, where turbulence is greater). Ascent rates for various balloons may be found in Smithsonian Meteorological Tables or other meteorological reference works. For this lab, an attempt will be made to track the balloon for at least 10 minutes per release, and heights achieved through 12 minutes for such a release are shown in Figure 9-4.

![Figure 9-4: The relationship between time after release and the height above ground level for a 30 gm pilot balloon.](image)

The heights for the 1:30 and 2:30 time marks are included in the figure to help in case the balloon position is not captured immediately after release.

**Distance Determination**

Values of the cotangent of the *elevation angle* (Figure 9-5) are required to calculate the horizontal distance of the balloon from the point of release. These values are provided in Table 9-1. Once this number has been provided, the ground distance to the balloon, needed for the calculation of wind speed, is determined from the following formula:

\[
\text{ground distance} = \text{height of balloon} \times \cotangle \text{ (elevation angle)}
\]

The theodolite readings generally are read to the nearest full degree for both *azimuth angle* and *elevation angle* (Figure 9-5 and 9-6, respectively). It is important that the theodolite be placed on a theodolite stand that is perfectly level with the horizon, providing a calibration for the elevation angle on the horizon of 0°. The azimuth must also be calibrated against a known landmark. From the roof of the Love Building, the flagpole atop the old Capitol Building is at an azimuth of 116° (from our permanently mounted stand). A second azimuth
marker is a helpful check and there is a church steeple in the woods just beyond the Medical School buildings at an azimuth of $257^\circ$. At other locations, two fixed reference points at least $120^\circ$ apart should be identified for theodolite use.

**TABLE 9-1:** Table of cotangent angles. To be used with the elevation angle only.

<table>
<thead>
<tr>
<th>elevation angle</th>
<th>cot</th>
<th>elevation angle</th>
<th>cot</th>
<th>elevation angle</th>
<th>cot</th>
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<th>cot</th>
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<tbody>
<tr>
<td>10</td>
<td>5.671</td>
<td>25</td>
<td>2.145</td>
<td>40</td>
<td>1.192</td>
<td>55</td>
<td>0.700</td>
<td>70</td>
<td>0.364</td>
</tr>
<tr>
<td>11</td>
<td>5.146</td>
<td>26</td>
<td>2.050</td>
<td>41</td>
<td>1.150</td>
<td>56</td>
<td>0.675</td>
<td>71</td>
<td>0.344</td>
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<tr>
<td>12</td>
<td>4.705</td>
<td>27</td>
<td>1.963</td>
<td>42</td>
<td>1.111</td>
<td>57</td>
<td>0.649</td>
<td>72</td>
<td>0.325</td>
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<td>13</td>
<td>4.331</td>
<td>28</td>
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<td>43</td>
<td>1.072</td>
<td>58</td>
<td>0.625</td>
<td>73</td>
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<td>14</td>
<td>4.011</td>
<td>29</td>
<td>1.804</td>
<td>44</td>
<td>1.036</td>
<td>59</td>
<td>0.601</td>
<td>74</td>
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<tr>
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<td>1.000</td>
<td>60</td>
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<td>46</td>
<td>0.966</td>
<td>61</td>
<td>0.554</td>
<td>76</td>
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</tr>
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<td>3.271</td>
<td>32</td>
<td>1.600</td>
<td>47</td>
<td>0.933</td>
<td>62</td>
<td>0.532</td>
<td>77</td>
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<tr>
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<td>33</td>
<td>1.540</td>
<td>48</td>
<td>0.900</td>
<td>63</td>
<td>0.510</td>
<td>78</td>
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<tr>
<td>19</td>
<td>2.904</td>
<td>34</td>
<td>1.483</td>
<td>49</td>
<td>0.869</td>
<td>64</td>
<td>0.488</td>
<td>79</td>
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<td>2.747</td>
<td>35</td>
<td>1.428</td>
<td>50</td>
<td>0.839</td>
<td>65</td>
<td>0.466</td>
<td>80</td>
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<td>21</td>
<td>2.605</td>
<td>36</td>
<td>1.376</td>
<td>51</td>
<td>0.810</td>
<td>66</td>
<td>0.445</td>
<td>81</td>
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<tr>
<td>22</td>
<td>2.475</td>
<td>37</td>
<td>1.327</td>
<td>52</td>
<td>0.781</td>
<td>67</td>
<td>0.424</td>
<td>82</td>
<td>0.141</td>
</tr>
<tr>
<td>23</td>
<td>2.356</td>
<td>38</td>
<td>1.280</td>
<td>53</td>
<td>0.754</td>
<td>68</td>
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<td>24</td>
<td>2.246</td>
<td>39</td>
<td>1.235</td>
<td>54</td>
<td>0.727</td>
<td>69</td>
<td>0.384</td>
<td>84</td>
<td>0.105</td>
</tr>
</tbody>
</table>

**FIGURE 9-5:** The rise of a pilot balloon, incorporating assumed ascent rates in the first few minutes. The elevation angle is also defined.
Wind Determination

The wind is determined by the minute-by-minute change in ground position. Distance to a given position is determined by the procedure shown above, using the elevation angle. The azimuth angle is used to determine the wind direction. This is defined as the angular change from true north along the horizon. It is measured clockwise starting with north as zero degrees (therefore east is 90°, south is 180°, etc.). The change in ground positions between the one-minute readings you will make yields the balloon ground track, as shown in Figure 9-7. The distance traveled each minute by the balloon will be the wind speed for that minute.

As an example, the change in azimuth angle between a hypothetical "3rd minute" and "4th minute" observation is shown in Figure 9-8. In the example, points are plotted for ground distance from the start for minutes 3 and 4 on a polar coordinate plot. An arrow is drawn from the 3rd to the 4th minute, and the length of this arrow is the ground track distance, or balloon ground track. The resultant wind is just the direction indicated by that arrow (or vector), and the wind speed is its length. The wind direction, remember, is the direction that the wind blows from. A protractor is generally required to accurately determine the wind direction to the nearest 1°.
Balloon Tracking Procedures

Once the theodolite has been set up properly, launch preparations are made, including safely inflating the helium balloon, tying it off adequately, and identifying tasks. Make sure that you start with the low power (4x telescope) and that everything is in focus (notice it will show object upside down. That won't matter for the balloon, however!). There should be at least one timer, one recorder, and one observer per launch team. The timer may launch the balloon. Immediately after launch, the balloon will be difficult to track even in quiet conditions. At this point the vernier knobs should be disengaged so that they move freely. It is helpful to have an individual behind the observer, siting the balloon through the gunsight at this point. As one minute approaches, the timer should provide a 10 and then 5-second countdown, saying "Mark" at the point when one minute has elapsed. At this point the observer should read the azimuth angle to the nearest degree, without changing the scales, and then the elevation angle. Don't worry if you lose sight of the balloon in this first minute - you will quickly find it again. The key point here is not to move the scales so that you obtain accurate readings of azimuth and elevation angles!

After a minute or so, the balloon will appear to have settled into a more orderly track under most circumstances, with deviations dictated by wind shear patterns aloft. You should engage the vernier knobs when it becomes apparent that only small changes in elevation and azimuth angles are occurring. Then use only the vernier knobs to move the apparatus, otherwise you will strip the gears...please take care to avoid forcing the telescope base to move by force with the vernier knobs locked down! After three to four minutes, you will probably need to switch to high power. Be sure to use the lens shield to protect yourself from direct or diffuse sunlight coming into the telescope, and never look directly at the sun (or even close to it!) through the telescope.
These steps are provided as guidelines:

1. Ensure that raising its temperature to near body temperature has preconditioned the balloon. This helps to ensure good elasticity and inflation. Use a warm water bath or body contact. For balloon color, use red if the sky is partly cloudy; otherwise use a natural or white balloon for a clear sky and a black balloon if the sky is overcast.

2. Make sure that the theodolite is level and that the azimuth has been set properly. Be sure to double check the azimuth angle reference points you have been given previously or for your particular location, if different.

3. Make sure everyone on each tracking team knows his or her roles. The observer generally follows the balloon in the telescope, and you may have a separate "reader" who reads the scales. It is important that the observer does not move the scales until the reader has called out both the angles, first azimuth, then elevation. The "recorder" should write down both readings at the proper minute mark, and the recorder may also be the timer or a separate timer can work for multiple groups working at the same time, tracking the same balloon.

4. The balloon is inflated with a special counterweight to ensure the proper buoyancy. A 139 gm counterweight is used for 30 gm balloons. That is also its free lift. Tie securely.

5. Avoid obstructions when the balloon is first launched, when things may be quite hectic. Have the reader help the observer by using the gunsights and make sure that the vernier knobs are not locked initially, so that the telescope may move freely through both angles. Record the time of the beginning of the observation (UTC).

6. Terminate the sounding when the balloon is lost, or after ten minutes, as directed by your instructor. Record the weather conditions at the time of launch and at the end of the flight.

Analysis Procedure

Once the balloon observation has been completed, the plotting of the observation can take place. Analysis follows these steps:

1. Record the height attained by the balloon at the end of each minute (use Figure 9-4).

2. Use Table 9-1 and the observed elevation angle to find the ground distance to the balloon,

   \[
   \text{ground distance} = \text{height of balloon} \times \cot(\text{elevation angle})
   \]

3. Plot each reading of azimuth angle and ground distance on the polar coordinate graph

4. Measure the distance during each successive period and record the results. Convert the wind speed to knots (from feet per minute) by dividing by 101.
5. Determine the direction of one-minute wind vectors with a protractor and record the results. You may have to "move" the vector to another part of the scale - make sure that you keep the same orientation!

**Example Determination**

Suppose the first two minutes were to yield the following measurements:

<table>
<thead>
<tr>
<th>Time</th>
<th>Elevation</th>
<th>Azimuth</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>45°</td>
<td>120°</td>
</tr>
<tr>
<td>2</td>
<td>30°</td>
<td>60°</td>
</tr>
</tbody>
</table>

The height of the balloon is found to be 709 ft after 1 minute and 1,358 ft after two minutes. The cotangent of the elevation angles is found to be 1.000 and 1.732, respectively, for these two elevation angles, and so the ground distance is

- distance (1 min) = 709 ft \times 1.000 = 709 ft
- distance (2 min) = 1358 ft \times 1.732 = 2,352 ft

The data are now ready for plotting, as shown in Figure 9-9.

**Figure 9-9:** Plotting a sample PIBAL observation. The observation for minute 1 ends at point 1 and the observation for minute 2 ends at point 2. A vector is drawn from the origin to point 1 to indicate the trajectory during the first minute. A vector is drawn between points 1 and 2 to represent the balloon trajectory during the second minute.
As drawn, a wind direction of 300° and a wind speed of 709 ft/min = 7 knots) is evident for the first minute. The speed of the second minute is found by measuring the length of the vector from point 1 to point 2; that distance is approximately 2,090 ft on the distance scale for the plot. The associated speed is 2,090 ft/min or 21 kt. The direction for the second minute may be found by using a circular protractor to obtain the angle of the vector connecting points 1 and 2. The angle will be the direction from which the wind is blowing (Figure 9-10).

![Protractor Diagram](image)

**Figure 9-10:** In the example PIBAL observation shown in Figure 9-9, the wind is blowing from 236° for the second minute.

The remaining observations are dealt with in the same manner. An observation table is shown in the exercise sheets. There are some helpful sites on the World Wide Web, including a humorous story of "Lawn Chair" Larry Walters (1949-1993), who lofted himself in a lawn chair and weather balloons. His stunt in 1982 earned him an honorable mention in the annual Darwin Awards and also a $1,500 fine from the Federal Aviation Administration.

- [http://www.csulb.edu/~mbrenner/calculat.htm](http://www.csulb.edu/~mbrenner/calculat.htm)
- [http://www.pilotballoon.com/computat.htm](http://www.pilotballoon.com/computat.htm)
- [http://www.noavalynx.com/400-balloons.html](http://www.noavalynx.com/400-balloons.html)
- [http://www.chem.hawaii.edu/uham/lift.html](http://www.chem.hawaii.edu/uham/lift.html)

4. **The Radiosonde and Rawinsonde Observation**

Although PIBALS are useful for sampling wind conditions in the lower troposphere, it is also desirable to obtain measurements of pressure, temperature, and humidity aloft with radiosondes. Many radiosonde-sampling sites are equipped with special radar systems that
can track the package by reflections from a radar reflector, or a GPS receiver. This yields range (distance to the balloon), as well as elevation and azimuthal angles. These are sufficient to determine the balloon position without recourse to assuming an ascension rate. Otherwise, the analysis is similar to that for the PIBAL. Such a package (and sounding) is termed rawinsonde.

Radiosondes are released twice daily with reporting times at midnight and noon, Greenwich, England time (also known as UTC as we have previously learned). There are approximately 120 sounding sites in the United States. The oceanic portions of the Earth (~70% of the surface area) are virtually unsampled, save by satellite and aircraft. The radiosonde report includes significant levels, as well as the mandatory levels shown in Table 9-2.

<table>
<thead>
<tr>
<th>TABLE 9-2: Approximate Pressure Surface Heights</th>
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</tr>
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</tr>
<tr>
<td>925</td>
</tr>
<tr>
<td>850</td>
</tr>
<tr>
<td>700</td>
</tr>
<tr>
<td>500</td>
</tr>
</tbody>
</table>

The day-to-day variations in density lead to pressure-height relations different from the tabular values above. As shown in the next exercise, the variations are mapped much like the sea level pressure.

The radiosonde temperature and moisture profiles are used to characterize atmospheric layers for their moisture content and stability. This assists the forecaster in the anticipation of clouds, perhaps showers, or even the early morning minimum temperature.

*This part of the present exercise seeks to illustrate the manner in which the pressure-height relation is determined for a single station – the first step in mapping the pressure height and determining the large-scale flow aloft.*

The quantitative basis for establishing the pressure-height relation is the hydrostatic equation, which we visited when we measured the barometric pressure differences between the basement and top of our building. For purposes, it can be expressed as

\[ |\Delta p| \approx \rho g |\Delta z| \]

or

\[
\text{pressure change} \approx \text{air density} \times \text{acceleration of gravity} \times \text{height difference}
\]

It’s easier to work in terms of temperature, and the relationship can be written with the *ideal gas law* as
height difference = |Δz| ≈ \frac{R}{g} |Δ \ln p|\overline{T}

Where R=287 J kg\(^{-1}\) K\(^{-1}\) is the gas constant for dry air and \(\ln p\) is the natural logarithm of pressure. The quantity \(\overline{T}\) is the mean value of temperature in the layer.

In practice, increasing the measured temperature slightly accommodates the presence of water vapor – leading to a lower air density –. The temperature increment added is proportional to the amount of moisture present. A virtual temperature is the result. The effect is the neglected here, so the layer thickness computed may be less than reported by the radiosonde report.

The mean temperature in a layer can be determine graphically, as suggested in the figure below:

![Schematic showing the procedure for obtaining a pressure-weighted mean (virtual) temperature sounding.](image)

**Figure 9-11**: Schematic showing the procedure for obtaining a pressure-weighted mean (virtual) temperature sounding.

The vertical line on the figure above defines the mean (virtual) temperature, serving to equalize the two-hatched areas.

After evaluation of the constants, the height difference formula is

\[ |Δz| = 29.3 \times \overline{T} \times \ln \left( \frac{p_{\text{bottom}}}{p_{\text{top}}} \right) \]

*In this case temperature is in Kelvin*

The height of any pressure surface is the sum of all the underlying height increments.
5. **Lab Instructions**

Provide your responses on pages A9-1 through A9-5, which consist of the pibal tally sheet, observation plot (polar coordinate) radiosonde data, a radiosonde calculation chart, and a virtual temperature chart and related question. Follow the instructions below:

1. **Pibal Observation.** The observational procedure laid out previously should be followed. As time permits and as instructed, you should also try to complete the radiosonde observation.

2. **Radiosonde Plot.** The radiosonde data shown in the tabular form on the following page has been plotted on the included diagram. Only the points between the 1000 hPa and the 500 hPa surfaces are shown. Insert the standard level heights found by the National Weather Service in the spaces provided on the diagram (these are found in the data tabulation).

3. **Mean Temperature Estimation.** Estimate the mean temperature in each of the three layers bounded by the standard levels (one of which is the surface, in this case) using the graphical technique illustrated in the lab. Tabulate the results on the form provided. Show your graphical evaluations – neatly!

4. **Layer Thickness.** Use the relation shown in the notes to compute the layer thickness. Note that its various factors are tabulated on the exercise sheet. Use the temperatures you found from the chart in part 2 of the lab to solve for thickness. Follow the calculations provided in the chart and lab to calculate thickness.

5. **Pressure Surface Heights.** Accumulate the layer thickness to determine the heights of the standard pressure levels. Tabulate these and those form the radiosonde sounding in the spaces provided. Remember, “the height of any pressure surface is the sum of all the underlying height increments.” Therefore, as you go up in height, lower in pressure, you have to add all the underlying heights before you can complete your calculation.

6. **Discussion.** Suggest reasons for the disparities, if any, in your estimated heights and those of the sounding. These are given in the note set and the lecture, so consider this important section well.
LAB #9

UPPER AIR OBSERVATIONS

NAME __________________________  SECTION # __________

DATE ____________________________ PARTNERS ____________________________

_________________________________________________________________________


Tally the observations from your pibal report. If you have data beyond 10 min, use the online Java applet shown in class to determine your wind observations, and tally them below. You must plot the first ten minutes of observational data here.

Observation Site: __________________________  Date: ____________________________

Time at start of observation: _______ UTC  Sky Condition: __________________________

Weather: __________________________  Winds: __________________________

Temperature: _______  Relative Humidity: _______  Pressure: __________

<table>
<thead>
<tr>
<th>OBSERVATIONS</th>
<th>CALCULATIONS</th>
<th>RESULTS</th>
</tr>
</thead>
<tbody>
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<td>Azimuth Angle</td>
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<tr>
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<td>709</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>1,368</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>2,007</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>2,627</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>3,247</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>3,638</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>4,228</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>5,019</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>5,609</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>6,199</td>
<td></td>
</tr>
</tbody>
</table>

See the instructions in the lab manual and follow your instructor’s lead in completing this table!
Next, plot the data as shown on the lab instructions on the sheet below. A larger sheet may be given to you to aid in the plotting. You will need to use this sheet to determine the wind speed and wind direction to fill in the table on the previous page.

**Figure A9-1:** Pibal plotting chart. The scale is user-definable here, and should represent conditions observed for your particular weather balloon launch.
2. [1] _______ The following data (978 hPa to 500 hPa) are plotted on Figure A9-2. Fill in the blanks to the right of the chart for each of the standard levels, in the spaces provided. The 925 hPa level was not a standard level (indicated by std) at the time of this observation, so it is not necessary to fill that value in here.

Sounding for Athens, GA, 16 November 1989, 0000 UTC

<table>
<thead>
<tr>
<th>Pressure (hPa)</th>
<th>Temperature (°C)</th>
<th>Dew Point (°C)</th>
<th>Height (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>978</td>
<td>20.6</td>
<td>17.5</td>
<td>246</td>
</tr>
<tr>
<td>959</td>
<td>21.0</td>
<td>17.3</td>
<td>416</td>
</tr>
<tr>
<td>850</td>
<td>13.6</td>
<td>10.7</td>
<td>1447</td>
</tr>
<tr>
<td>769</td>
<td>7.8</td>
<td>6.9</td>
<td>2284</td>
</tr>
<tr>
<td>700</td>
<td>3.0</td>
<td>−3.0</td>
<td>3055</td>
</tr>
<tr>
<td>665</td>
<td>0.0</td>
<td>−2.8</td>
<td>3470</td>
</tr>
<tr>
<td>636</td>
<td>−1.7</td>
<td>−6.7</td>
<td>3827</td>
</tr>
<tr>
<td>615</td>
<td>−2.5</td>
<td>−13.5</td>
<td>4094</td>
</tr>
<tr>
<td>610</td>
<td>−2.5</td>
<td>−32.5</td>
<td>4159</td>
</tr>
<tr>
<td>500</td>
<td>−11.9</td>
<td>−41.9</td>
<td>5710</td>
</tr>
</tbody>
</table>

Figure A9-2: Plot of data shown in #2. Fill in the calculated height of the standard pressure surface directly on the chart in the blanks on the right hand side.

Evaluate the mean temperature of each of the three layers bounded by the standard levels, following the procedure shown in the instructions. Tabulate the results in the space provided below (for #4). Since the surface pressure here is less than 1,000 hPa, it becomes a standard level here. The elevation at Athens, GA is 246 m above sea level. Please show your work!

4. [1] _______ Layer Thicknesses

Use the formula

\[ |\Delta z| = 29.3 \times \bar{T} \times \ln\left(\frac{p_{\text{bottom}}}{p_{\text{top}}}\right) \]

to evaluate the layer thicknesses in the table below:

| Layer        | Layer Mean Temperature (K) | \( \ln\left(\frac{p_{\text{bottom}}}{p_{\text{top}}}\right)\) | Layer Thickness (|\Delta z|) |
|--------------|-----------------------------|----------------------------------------------------------|-----------------------------|
| 978 – 850 hPa| 0.1403                      |                                                          |                             |
| 850 – 700 hPa| 0.1942                      |                                                          |                             |
| 700 – 500 hPa| 0.3365                      |                                                          |                             |
5. [1] _______ Pressure Surface Heights

Tabulate the radiosonde-indicated heights below. Find the accumulated heights from the differences calculated above and tabulate them.

<table>
<thead>
<tr>
<th>Level</th>
<th>Plotted Height (m)</th>
<th>Calculated Height (m)</th>
<th>Difference (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>850 hPa</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>700 hPa</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>500 hPa</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

6. [1] _______ Discussion. Please suggest any reasons for any discrepancies between your standard pressure heights and those actually reported by the radiosonde. Also, can you tell why the reports at 615 and 610 hPa were provided?
THIS PAGE PURPOSELY LEFT BLANK.
APPENDIX D: TEACHING ASSISTANT LAB SURVEY

Name:

Number of Semesters you have taught MET 1010 (including present semester):

In the context of working in teams, tasks can generally be described as **unitary** or **divisible**.

**Unitary**: Tasks that cannot profitably be divided into subtasks and performed in piecemeal fashion by two or more individuals in the team. Example – having a group discussion on a weather event.

**Divisible**: Tasks that make a division of labor feasible where subtasks can be performed by individuals in the team. Example – writing the names of each state, lake, and province on a map.

The idea is whether teams mainly use a working in unison (unitary) or a divide and conquer (divisible) approach to each lab assignment.

Given the above definitions, please rate each of the specified labs on the 10pt scale below. Indicate how you perceive the lab by circling (or highlighting) the appropriate number. Base your responses on student observation while teaching the MET 1010 labs as well as the lab assignment descriptions (please use your lab manual).

<table>
<thead>
<tr>
<th>Lab assignment 7 (Hurricanes) tasks are…</th>
<th>Unitary</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Divisible</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Lab assignment 8 (ENSO) tasks are…</th>
<th>Unitary</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Divisible</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Lab assignment 9 (Upper Air Obs.) tasks are…</th>
<th>Unitary</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Divisible</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Lab assignment 12 (Interstate Climatology) tasks are…</th>
<th>Unitary</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Divisible</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

End of Survey. Thank you! Please be sure to **Save** before emailing back.
APPENDIX E: TEAM QUIZ

Lab Instructor: __________________________
Team #: __________________________
Team member names:

**MET 1010 Team Quiz**
**Fall 2008**

As a team, please work together to reach a consensus on the answers to the following questions. You will submit only one quiz per team so please be sure to reach an agreement for each response. This quiz covers Labs 7, 8, and 9.

**Part I: Multiple Choice (5 pts)**

1. What are the dates for the North Atlantic Hurricane Season?
   a. June 1\(^{st}\) – November 30\(^{th}\)
   b. July 1\(^{st}\) – November 30\(^{th}\)
   c. June 1\(^{st}\) – December 31\(^{st}\)
   d. July 1\(^{st}\) – December 31

2. Where are the most intense winds and heaviest rain of a hurricane located?
   a. The Eye
   b. The Outside Edge
   c. Halfway from the Edge to the Eye
   d. The Eye Wall

3. Which of the following is the **least** likely location for a hurricane to form?
   a. The Caribbean
   b. The Gulf of Mexico
   c. The Northern Latitudes of the Atlantic
   d. Off the Coast of Africa

4. El Nino causes:
   a. Dryer, cooler winters in the Southeast United States
   b. Wetter, cooler winters in the Southeast United States
   c. Dryer, warmer winters in the Southeast United States
   d. Wetter, warmer winters in the Southeast United States

5. In an El Nino year, unusually warm water can be found off the coast of:
   a. Canada and the United States
   b. Africa
   c. Australia and New Zealand
   d. France
Part II: True / False (5 pts)

6. A storm is given a name when it first becomes a hurricane?
   TRUE          FALSE

7. Making landfall will cause a hurricane to weaken?
   TRUE          FALSE

8. The name of the scale for hurricane intensity is The Fujita Scale?
   TRUE          FALSE

9. More hurricanes are likely to form in the Atlantic Ocean during an El Nino year as compared to other years?
   TRUE          FALSE

10. During an El Nino cycle, trade winds in the Pacific Ocean strengthen their westward motion?
    TRUE          FALSE
Part III: Short Answer (5 pts)

Using the data below and the provided sounding scale, plot the position of the pilot balloon.

<table>
<thead>
<tr>
<th>Observation #</th>
<th>Azimuth Angle</th>
<th>Ground Distance</th>
<th>Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>200°</td>
<td>1,000 ft</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>220°</td>
<td>2,000 ft</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>240°</td>
<td>3,000 ft</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>210°</td>
<td>4,000 ft</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>180°</td>
<td>5,000 ft</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>160°</td>
<td>6,000 ft</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>140°</td>
<td>7,000 ft</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>150°</td>
<td>8,000 ft</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>170°</td>
<td>9,000 ft</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>190°</td>
<td>10,000 ft</td>
<td></td>
</tr>
</tbody>
</table>
MET 1010 Fall Study Demographics Template

1. SSN (last 4 digits)*
   used as an identifier (will be kept confidential)

2. Last Name, First Name*
   Enter your name.

3. What team are you on? *
   Choose your team from the list below.
   -- Please Select --

4. Name of Lab Instructor *
   -- Please Select --

5. Date *

6. Participant Age *

7. Gender *
   ○ Male  ○ Female

8. Race *
   ○ Asian / Pacific Islander  ○ Black / African American  ○ White / Caucasian  ○ Hispanic / Latino  ○ Native American  ○ Other, please specify

9. How many credit hours have you completed prior to this semester? *
   DO NOT COUNT HIGH SCHOOL

10. How many semesters have you completed as a student in higher education (i.e. BEYOND HIGH SCHOOL)? *
    If this is your first semester, write a 0 in the space

APPENDIX F: DEMOGRAPHIC SURVEY
11. Major of Study

12. Do you have any previous experience with Meteorology concepts beyond this course?
   - Yes  
   - No
   - If yes, briefly explain your experience(s) with Meteorology concepts.

13. In general, what is your skill level related to Meteorology lab assignment tasks?
   - Very Low  
   - Low  
   - Medium  
   - High  
   - Very High

14. In general, what is your team members' skill level related to the Meteorology lab assignment tasks?
   - Very Low  
   - Low  
   - Medium  
   - High  
   - Very High

15. Do you have any previous experience working with your teammates outside of this lab?
   - Yes  
   - No
   - If yes, briefly explain the extent of your prior experience(s) working with your teammates.

16. Do you have any previous experience working with your teammates in this lab?
   - Yes  
   - No
   - If yes, briefly explain the extent of your prior experience(s) working with your teammates.

17. In general, what is your ability level to successfully work in a team?
   - Very Low  
   - Low  
   - Medium  
   - High  
   - Very High

18. In general, what is your teammates' ability to successfully work in a team?
1. Lab Assignment Submitted
This is the very latest lab assignment you submitted as a team to your TA

2. Name
Enter your Last Name, First Name.

3. Name of Lab Instructor

4. What team are you on?
Choose your team from the list below.

5. The lab assignment we just submitted was complex

6. The lab assignment we just submitted was stressful

7. The lab assignment we just submitted was difficult for me

8. The amount of work was high for the lab assignment we just submitted

9. The lab assignment we just submitted was mentally challenging

10. A wide variety of tasks had to be completed for the lab assignment we just submitted

11. To this point, how many lab assignments have you worked on with your team?

12. What is your satisfaction level with your team on this lab assignment?

13. What is your frustration level with your team on this lab assignment?

14. My team usually discusses our goals and attains the agreement of each other. (1.7)
15. My team knows specific strategies for completing our tasks. (1.8*)
   - Strongly Disagree  - Disagree  - Neutral  - Agree  - Strongly Agree

16. My team knows the general process involved in carrying out our tasks. (1.9*)
   - Strongly Disagree  - Disagree  - Neutral  - Agree  - Strongly Agree

**Factor 2—General Task and Communication Skills**

17. My team communicates effectively with each other while performing our tasks. (2.11*)
   - Strongly Disagree  - Disagree  - Neutral  - Agree  - Strongly Agree

18. My teammates consistently demonstrate effective listening skills (2.16).*
   - Strongly Disagree  - Disagree  - Neutral  - Agree  - Strongly Agree

19. Everybody in my team strives to express his or her opinion (2.24).*
   - Strongly Disagree  - Disagree  - Neutral  - Agree  - Strongly Agree

**Factor 3—Attitude Toward Teammates and Task**

20. My team likes to do various team tasks. (3.17*)
   - Strongly Disagree  - Disagree  - Neutral  - Agree  - Strongly Agree

21. My team encourages each other in order to improve our outcomes. (3.18*)
   - Strongly Disagree  - Disagree  - Neutral  - Agree  - Strongly Agree

22. My team takes pride in our work. (3.19*)
   - Strongly Disagree  - Disagree  - Neutral  - Agree  - Strongly Agree

**Factor 4—Team Dynamics and Interactions**

23. My team is likely to make decisions together. (4.29*)
   - Strongly Disagree  - Disagree  - Neutral  - Agree  - Strongly Agree

24. My team understands how we can exchange information for doing our tasks. (4.32*)
   - Strongly Disagree  - Disagree  - Neutral  - Agree  - Strongly Agree

25. My team solves problems that occur while doing our tasks. (4.33*)
   - Strongly Disagree  - Disagree  - Neutral  - Agree  - Strongly Agree

**Factor 5—Team Resources and Working Environment**

26. My team creates a safe environment to openly discuss any issue related to the team’s success. (5.36*)
   - Strongly Disagree  - Disagree  - Neutral  - Agree  - Strongly Agree

27. My team has the right experience so that a critical mass of experienced people is available on the team. (5.41*)
   - Strongly Disagree  - Disagree  - Neutral  - Agree  - Strongly Agree

28. My team knows the environmental constraints when we perform our tasks. (5.42*)
   - Strongly Disagree  - Disagree  - Neutral  - Agree  - Strongly Agree

29. For each of the following items, please rate the level of relatedness.
   - Totally Unrelated: Having a lot of one has no relationship to another one.
   - Highly Related: Having a lot of one means you have a lot of another one.
| Knowledge (about tasks and team) AND Skills (related to tasks and communications) | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Knowledge (about tasks and team) AND Attitudes (towards team and tasks) | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Knowledge (about tasks and team) AND Dynamics (interactions within team) | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Knowledge (about tasks and team) AND Environmental Factors (culture, organization, location) | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Skills (related to tasks and communications) AND Attitudes (towards team and tasks) | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Skills (related to tasks and communications) AND Dynamics (interactions within team) | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Skills (related to tasks and communications) AND Environmental Factors (culture, organization, location) | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Attitudes (towards team and tasks) AND Dynamics (interactions within team) | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Attitudes (towards team and tasks) AND Environmental Factors (culture, organization, location) | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Dynamics (interactions within team) AND Resources (technology, tools, and people) | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Dynamics (interactions within team) AND Environmental Factors (culture, organization, location) | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Resources (technology, tools, and people) AND Environmental Factors (culture, organization, location) | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
APPENDIX H: HUMAN SUBJECTS APPROVAL and INFORMED CONSENT FORM

Approval Letter

Office of the Vice President For Research
Human Subjects Committee
Tallahassee, Florida 32306-2742
(850) 644-8673 • FAX (850) 644-4392

APPROVAL MEMORANDUM

Date: 2/11/2008

To: Eric Sikorski [egs04@fsu.edu]

Address: 2055 Thomasville Rd. Apt. B 105 Tallahassee FL 32308
Dept.: EDUCATIONAL PSYCHOLOGY AND LEARNING SYSTEMS

From: Thomas L. Jacobson, Chair

Re: Use of Human Subjects in Research
Shared Mental Models, Team Performance, and Interaction Patterns. Examining the Effects of a Process Intervention in a Team Based Learning Environment

The application that you submitted to this office in regard to the use of human subjects in the proposal referenced above have been reviewed by the Secretary, the Chair, and two members of the Human Subjects Committee. Your project is determined to be Expedited per 45 CFR § 46.110(7) and has been approved by an expedited review process.

The Human Subjects Committee has not evaluated your proposal for scientific merit, except to weigh the risk to the human participants and the aspects of the proposal related to potential risk and benefit. This approval does not replace any departmental or other approvals, which may be required.

If you submitted a proposed consent form with your application, the approved stamped consent form is attached to this approval notice. Only the stamped version of the consent form may be used in recruiting research subjects.

If the project has not been completed by 2/6/2009 you must request a renewal of approval for continuation of the project. As a courtesy, a renewal notice will be sent to you prior to your expiration date; however, it is your responsibility as the Principal Investigator to timely request renewal of your approval from the Committee.

You are advised that any change in protocol for this project must be reviewed and approved by the Committee prior to implementation of the proposed change in the protocol. A protocol change/amendment form is required to be submitted for approval by the Committee. In addition, federal regulations require that the Principal Investigator promptly report, in writing any unanticipated problems or adverse events involving risks to research subjects or others.

By copy of this memorandum, the Chair of your department and/or your major professor is reminded that he/she is responsible for being informed concerning research projects involving human subjects in the department, and should review protocols as often as needed to insure that the project is being conducted in compliance with our institution and with DHHS regulations.

This institution has an Assurance on file with the Office for Human Research Protection. The Assurance Number is IRB00000446.

Cc: Tristan Johnson, Advisor [tjohnson@lsfa.fsu.edu]
HSC No. 2008.1071

Dear Students,

The purpose of this study is to investigate the relationships between team processes, performances, and interaction in the instructional environment. In this study, we will examine the development of team shared mental models in terms of the task and team-related mental models. We will be studying interaction patterns and how these relate to performance and shared mental model development. The ultimate goal is to improve team performance in the instructional environment.

During this study, you will be involved in answering questions about your team and task mental model. Your teams will be engaged in an activity that calls for communication between team members and the development of a shared understanding about the complex problems. These activities employ many of the abilities and skills needed in the successful performance of duties that require communication and shared understanding among team members. You may be observed and videotaped throughout the study.

Specific Procedures to be Used

Participants will be asked to complete the following data collection activities:

- Complete one demographic survey (less than 10 minutes)
- Complete a series of questionnaires during a particular unit of instruction (5-15 times at 10 minutes each)
- Complete individual performance assessments (30 minutes each)
- Complete one peer rated individual assessment (30 minutes)
- Complete team performance assessments

Duration of Participation

Questionnaires will be used to investigate the mental model development when working in teams in an instructional environment. Information from questionnaires, observations, videotapes, and performance assessments will also be used to understand how teams communicate and develop a shared level of understanding about the task in terms of team-related mental model. The time commitment for answering the questionnaires is approximately 20 minutes per week. The time commitment for completing performance assessments depends on the number of quizzes.
administered by the course professor. The time spent in team collaboration need not exceed the
time necessary to complete the lab assignments as detailed in the course syllabus.

Confidentiality
If you volunteer for this data collection, your confidentiality will be maintained to the extent
allowed by law by the following procedures:

- Survey data will be coded, the data transferred into a database, and
  participants’ names never associated with the data again.
- All data sources will be kept in locked file cabinets in the office of the
  Principle Investigator at Learning Systems Institute, Florida State
  University.
- Upon completion of the study, all raw data sources will be appropriately
  destroyed within six months following the study.

Risks
The use of data collection methods identified above does not present any potential risk to the
participants who volunteer for participation.

Benefits
Participants will have the opportunity to reflect on their problem solving processes by
completing the cognitive measures. Participants also get experience working in teams and
collaborating to solve problems in the instructional environment. This collaboration also gives
participants to access to knowledge that they may not have obtained working on their own.

Voluntary Nature of Participation
You do not have to participate in this study. If you do not wish to be involved in the data
collection, your grade will not be negatively impacted. If you agree to volunteer for participation
in this study, and at any time wish to withdraw your participation, you may do so without penalty
or loss of benefits. If you choose to withdraw participation, you may do so by letting the
Principle Investigator know during the class. Alternately, you may contact Eric Sikorski at the
Learning Systems Institute, Florida State University via phone (850) 559-4720 or email
egs04@fsu.edu.

Human Subject Statement:
If you have any questions about this study, please contact Eric Sikorski at the Learning Systems
Institute, Florida State University (850) 559-4720. If you have any questions about your rights as
a subject/participant in this study, or if you feel you have been placed at risk, you may contact
the following:

Chair of FSU Human Subjects Committee
2010 Levy Avenue, Suite 276-C
Tallahassee, FL 32306-2743
Ph: (850) 644-7900
Informed Consent
If you choose to participate in this study, please indicate your consent by signing and returning
one copy of the accompanying participant consent form. If at any time you have any questions
regarding this study, please do not hesitate to Eric G. Sikorski at the Learning Systems Institute,
Florida State University by phone (850) 575-0405 or email egs04@fsu.edu.

Sincerely,

Eric G. Sikorski
Learning Systems Institute, Florida State University
2000 Levy Avenue
Tallahassee, FL 32310
Phone: (850) 575-0405
Email: egs04@fsu.edu

Tristan E. Johnson
LSI, Florida State University
4600-C University Center
Tallahassee, FL 32310
Phone: (850) 644-8770
Email: tjohnson@lsi.fsu.edu
REFERENCES


Ensley, G. (2008). It never rains at Tallahassee's airport (and other weather myths). Tallahassee Democrat,


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Mohammed, S., Klimoski, R., & Rentsch, J. R. (2000). The measurement of team mental models: We have no shared schema. *Organizational Research Methods, 3*, 123-165.


BIOGRAPHICAL SKETCH

EDUCATION

PhD: Instructional Systems · Florida State University
Department of Educational Psychology and Learning Systems
College of Education, Tallahassee, FL
Focus area: Human Performance Technology
Minor: Communications

MS: Instructional Systems · Florida State University
Department of Educational Psychology and Learning Systems
College of Education, Tallahassee, FL
Degree conferred December 2005

BA: Honours Psychology · Brock University
Psychology Department
Thorold, Ontario
Degree conferred April 2004
Graduated with First Class Standing

CERTIFICATES

FSU College of Communication Project Management Certificate
Obtained October 2007

FSU Instructional Systems Program Human Performance Technology Certificate
Obtained August 2007

RESEARCH PROJECT EXPERIENCE

Project Manager · FSU – US Air Force Research Lab IMPRINT 2 Project · 2007 – Present


Research Assistant · US Navy Education and Training Command Project · 2004 - 2006

Lab Intern · FSU Complex Cognitive Skills Acquisition and Transfer Lab · 2005

INSTRUCTIONAL DESIGN and PERFORMANCE IMPROVEMENT EXPERIENCE

Course Designer · FSU Educational Psychology Graduate Courses · 2006 – 2008

A Systems Approach to the Management of Change (EME 6636):
Managing Instructional Development (EME 6631 – online)
Instructional Materials Development (EDG 6925)
Workshop Developer · Team Based Learning Workshops · 2007 – 2008

Team Lead · Performance Systems Analysis (PSA) at Tallahassee Museum · Fall 2005

TEACHING EXPERIENCE

Co-Instructor: Analysis of Variance · Summer 2008

Teaching Assistant: Managing Instructional Design · Spring 2008

Seminar Leader / Teaching Assistant: Media Fantasy and Reality · Spring 2004

Seminar Leader: Personality and Individual Differences · Spring 2004

Seminar Leader: Introduction to Psychology · Fall 2001 - Spring 2003

PUBLICATIONS and PRESENTATIONS

Publications

Peer Reviewed Journal Articles


Book Chapters


Presentations

Sikorski, E. G. & Johnson, T. E. Team Knowledge Sharing Intervention Effect of Team Shared Mental Models and Team Performance in an Undergraduate Meteorology Course. Accepted as a Featured Research presentation at the Association for Educational Communications and Technology Convention (2009) Louisville, KY


Sikorski, E. G. *Team Knowledge Sharing Intervention Effects on Team Shared Mental Models and Team Performance in an Undergraduate Meteorology Course*. Invited presentation to an international audience at the monthly International Center for Learning and Enhanced Performance Studies research exchange (2009) Tallahassee, FL.

Sikorski, E. G. *Predicting the Impact of Training on Performance: Maintenance Study*. Presented as part of a panel discussion at the Interservice/Industry Training, Simulation and Education Conference (2008) Orlando, FL

Sikorski, E. G. *Shared Mental Model Development and Performance in a Team-Based Learning Environment*. Poster presented at the Association for Educational Communications and Technology Convention (2008) Orlando, FL


### AWARDS

- Ruby Diamond Instructional Systems Future Professor Award · 2008
- Gagne – Briggs Instructional Systems Doctoral Student of the Year finalist · 2008
- Gagne – Briggs Instructional Systems Outstanding Student Service Award · 2006 and 2007
- PacifiCorp Design and Development Competition finalist · 2006
- Gagne – Briggs Instructional Systems Masters Student of the Year Award · 2005
- Charleston Partners ISD scholarship · 2004
- Brock University Deans Honour’s List · 2000 – 2004

### ACADEMIC SERVICE

- Assistant to AECT Training and Performance Division President Elect · 2008 – 2009
- FSU Instructional Systems Faculty Search Committee Student Representative · 2008 – 2009
- FSU Instructional Systems Alumni Advisory Council Committee Member · 2008 - 2009
- TechTrends Magazine Article Reviewer · 2008
- ISPI Annual Conference Proposal Reviewer · 2008
- President: FSU Instructional Systems Student Association (ISSA) · 2006 – 2008
- Vice President Social Events: FSU ISSA · 2005 – 2006

### PROFESSIONAL MEMBERSHIPS

- Association for Educational Communications and Technology (AECT)
- American Educational Research Association (AERA)
- International Center for Learning and Enhanced Performance Studies (ICLEPS)