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UNDERSTANDING CHANGES IN TEAM-RELATED AND TASK-RELATED
MENTAL MODELS AND THEIR EFFECTS ON TEAM AND INDIVIDUAL
PERFORMANCE

By

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TABLE OF CONTENTS

LIST OF TABLES.....	ix
LIST OF FIGURES.....	xii
ABSTRACT.....	xiii
CHAPTER I: INTRODUCTION.....	1
Purpose of Study.....	5
Research Questions.....	6
Research Question 1: Does SMM change over time?.....	6
Research Question 2: Is Team-SMM or Task-SMM a better predictor of performance at the team and/or individual level?.....	6
Significance of Study.....	7
CHAPTER II: THEORETICAL BACKGROUND.....	8
Theoretical Background.....	9
Team Cognition.....	9
Shared Understanding.....	10
Shared Knowledge.....	11
Shared Mental Models.....	11
Relationships among Terms.....	12
Shared Mental Model Development Framework.....	13
Types of Shared Mental Models.....	14
Change of Shared Mental Models over Time.....	17
Measuring Shared Mental Models.....	19
Variables to Consider when Measuring SMM.....	20
Team Size.....	20
Task Complexity.....	21
Skill-Levels of Team Members.....	21
Team Performance and Individual Performance.....	22
Summary.....	22
CHAPTER III: METHODOLOGY.....	23
Participants.....	23
Team Project.....	25
Instrumentation.....	27
Measuring Shared Mental Models.....	27
Measuring Team-SMM Structure (Appendix D).....	28

Measuring Team-SMM Degree (Appendix E)	29
Measuring Task-SMM Structure (Appendices F, G, H).....	30
Measuring Task-SMM Degree (Appendices I, J, K, L).....	32
Measuring Performance	33
Measuring Team Performance (Appendix M).....	33
Measuring Individual Performance (Appendices N, O, P).....	33
Data Collection Procedures.....	34
Team-SMM Data Collection.....	34
Task-SMM Data Collection.....	35
Performance Data Collection.....	35
Data Analysis	36
Similarity Score Analysis.....	37
Guiding Question 1—Does SMM change over time?.....	37
Guiding Question 2—Is Team-SMM or Task-SMM the better predictor of performance?	38
CHAPTER IV: RESULTS.....	41
Introduction	41
Descriptive Data	41
Change of Shared Mental Models	45
Change of Team-SMM Structure and Team-SMM Degree over time.....	45
Change of Post Score in Team-SMM Structure Similarity	45
Change of Growth Score in Team-SMM Structure Similarity.....	46
Change of Post Score in Team-SMM Degree (Variance).....	48
Change of Growth Score in Team-SMM Degree (Variance)	48
Change of Post Score in Team-SMM Degree (Average)	51
Change of Growth Score in Team-SMM Degree (Average).....	52
Change of Task-SMM Structure and Task-SMM Degree over time	54
Change of Post Score in Task-SMM Structure	54
Change of Growth Score in Task-SMM Structure	55
Change of Post Score in Task-SMM Degree (Variance).....	57
Change of Growth Score in Task-SMM Degree (Variance).....	57
Change of Post Score in Task-SMM Degree (Average).....	59
Change of Growth Score in Task-SMM Degree (Average)	60
Summary of the Changes in Team-SMM and Task-SMM	61
Is Team-SMM or Task-SMM the better predictor of performance?	65
Team Performance: Team-SMM or Task-SMM.....	68
Post Score of SMMs Structure and Team Performance	68
Growth Score of SMMs Structure and Team Performance.....	70
Post Score of SMMs Degree (Variance) and Team Performance	71
Growth Score of SMMs Degree (Variance) and Team Performance	72
Post Score of SMMs Degree (Average) and Team Performance	74
Growth Score of SMMs Degree (Average) and Team Performance.....	75

Predicting Individual Performance by Team-SMM and Task-SMM.....	77
Post score of SMMs Structure and Individual Performance	77
Growth Score of SMMs Structure and Individual Performance	78
Post score of SMMs Degree (Variance) and Individual Performance	80
Growth Score of SMMs Degree (Variance) and Individual Performance	81
Post Score of SMMs Degree (Average) and Individual Performance.....	83
Growth Score of SMMs Degree (Average) and Individual Performance	84
Summary of the Best Predictor in Team and Individual Performance over Time.....	86
CHAPTER V: DISCUSSION	88
Introduction.....	88
1. Does SMM change over time?.....	89
Change of Team-SMM	89
Change of Task-SMM.....	91
2. Is Team-SMM or Task-SMM the better predictor of performance?	93
SMMs Structure and Performance	93
SMMs Degree (Variance) and Performance.....	94
SMMs Degree (Average) and Performance.....	94
Summary	96
Limitations of the Study	97
Implications.....	99
Future Research.....	101
Conclusions.....	103
APPENDIX A. TASK ANALYSIS	106
APPENDIX B. TEAM PROJECT: PHASE I, II, III.....	107
APPENDIX C. Demographic Survey	108
APPENDIX D. Team-SMM Structure: Phase I, II, III.....	110
APPENDIX E. Team-SMM Degree: Phase I, II, III	112
APPENDIX F. Task-SMM Structure: Phase I.....	113
APPENDIX G. Task-SMM Structure: Phase II.....	114
APPENDIX H. Task-SMM Structure: Phase III	115
APPENDIX I. Task-SMM Degree: Pre-Phase I.....	116
APPENDIX J. Task-SMM Degree: Between Phase I and Phase II	117
APPENDIX K. Task-SMM Degree: Between Phase II and Phase III	118
APPENDIX L. Task-SMM Degree: Post-Phase III	119
APPENDIX M. Team Performance Measures	120

APPENDIX N. Individual Performance Measures: Phase I	121
APPENDIX O. Individual Performance Measures: Phase II.....	122
APPENDIX P. Individual Performance Measures: Phase III.....	123
APPENDIX Q. Human Subject Approval Memorandum and Informed Consent Form	124
REFERENCES.....	126
BIOGRAPHICAL SKETCH.....	132

LIST OF TABLES

Table 3.1. <i>Description of Team-SMM Structure Components</i>	28
Table 3.2. <i>Task-SMM Structure Components for each Team Project Phase</i>	31
Table 4.1. <i>Means and SDs for Team performance, Individual performance, Team-SMM related variables and Task-SMM related variables</i>	42
Table 4.2. <i>Means and SDs of Post Score in Team-SMM Structure</i>	46
Table 4.3. <i>Means and SDs of Growth Score in Team-SMM Structure</i>	46
Table 4.4. <i>Means and SDs of Post Score in Team-SMM Degree (Variance)</i>	48
Table 4.5. <i>Means and SDs for perceptions about Team-SMM Degree (Variance)</i>	49
Table 4.6. <i>Means and SDs of Post Score in Team-SMM Degree (Average)</i>	51
Table 4.7. <i>Means and SDs for Growth Score about Team-SMM Degree (Average)</i>	52
Table 4.8. <i>Means and SDs of Post Score in Task-SMM Structure</i>	54
Table 4.9. <i>Means and SDs of Growth Score of Task-SMM Structure</i>	55
Table 4.10. <i>Means and SDs of Post Score in Task-SMM Degree (Variance)</i>	57
Table 4.11. <i>Means and SDs of Growth Score in Task-SMM Degree (Variance)</i>	58
Table 4.12. <i>Means and SDs of Post Score in Task-SMM Degree (Average)</i>	59

Table 4.13. <i>Means and SDs of the Growth Score in Task-SMM Degree (Average)</i>	60
Table 4.14. <i>Summary of the Change of Team-SMM and Task-SMM</i>	62
Table 4.15. <i>Example of the Restructured Data Set with Time Dummy Variables</i>	66
Table 4.16. <i>Results from Random Effects GLS Regression of the Post Scores of Task-SMM Structure and Team-SMM Structure on Team Performance</i>	69
Table 4.17. <i>Results from Random Effects GLS Regression of the Growth Scores of Task-SMM Structure and Team-SMM Structure on Team Performance</i>	70
Table 4.18. <i>Results from Random Effects GLS Regression of the Post Scores of Task-SMM Degree (Variance) and Team-SMM Degree (Variance) on Team Performance</i>	72
Table 4.19. <i>Results from Fixed-Effects Regression of the Growth Scores of Task-SMM Degree (Variance) and Team-SMM Degree (Variance) on Team Performance</i>	73
Table 4.20. <i>Results from Fixed Effects Regression of the Post Scores of Task-SMM Degree (Average) and Team-SMM Degree (Average) on Team Performance</i>	75
Table 4.21. <i>Results from Fixed Effects Regression of the Growth Scores of Task-SMM Degree (Average) and Team-SMM Degree (Average) on Team Performance.</i>	76
Table 4.22. <i>Results from Random Effects GLS Regression of the Post Scores of Task-SMM Structure and Team-SMM Structure on Individual Performance</i>	78
Table 4.23. <i>Results from Random Effects GLS Regression of the Growth Scores of Task-SMM Structure and Team-SMM Structure on Individual Performance</i>	79
Table 4.24. <i>Results from Random Effects GLS Regression of the Post Scores of Task-SMM Degree (Variance) and Team-SMM Degree (Variance) on Individual Performance</i>	81

Table 4.25. <i>Results from Random Effects GLS Regression of the Growth Scores of Task-SMM Degree (Variance) and Team-SMM Degree (Variance) on Individual Performance</i>	82
Table 4.26. <i>Results from Random Effects GLS Regression of the Post Scores of Task-SMM Degree (Average) and Team-SMM Degree (Average) on Individual Performance</i>	84
Table 4.27. <i>Results from Random Effects GLS Regression of the Growth Scores of Task-SMM Degree (Average) and Team-SMM Degree (Average) on Individual Performance</i>	85
Table 4.28. <i>Summary of the Tested Hypotheses and Results</i>	87

LIST OF FIGURES

<i>Figure 3.1.</i> Example for Measuring the Structure of Shared Mental Model.....	29
<i>Figure 3.2.</i> Team-SMM Structure and Team-SMM Degree Data Collection Procedure	35
<i>Figure 3.3.</i> Task-SMM Structure and Task-SMM Degree Data Collection Procedure.....	35
<i>Figure 3.4.</i> Team and Individual Performance Data Collection Procedures	36
<i>Figure 4.1.</i> Frequency distributions of the overall team performance score and individual performance score.....	43
<i>Figure 4.2.</i> Line Plot of the Relationship between Time and Performance.	44
<i>Figure 4.3.</i> Changes of Post score and Growth Score of Team-SMM Structure.....	47
<i>Figure 4.4.</i> Changes of Post score and Growth Score of Team-SMM Degree (Variance).....	50
<i>Figure 4.5.</i> Change of the Post Score and Growth Score in Team-SMM Degree (Average).....	53
<i>Figure 4.6.</i> Change of the Post Score and Growth Score in Task-SMM Structure	56
<i>Figure 4.7.</i> Change of Post score and Growth Score in Task-SMM Degree (Variance)	58
<i>Figure 4.8.</i> Change of Post score and Growth Score in Task-SMM Degree (Average).....	61
<i>Figure 4.9.</i> Graphical Representation of the Changes in Team-SMM and Task-SMM in terms of their Structure, Degree (Variance), and Degree (Average).....	63

ABSTRACT

This study originated from efforts to find ways to enhance team and individual performance in team-based projects. Through literature reviews, it was recognized that the theory of shared mental models has explained the close relationship between shared mental models and performance. Even though many researchers have studied shared mental models, the field of studies is still developing. From building a robust theory to the application of the theory, many research topics remain unanswered. Among many veiled research issues, this study focused on uncovering the underlying mechanism that can explain the dynamic relationship between shared mental models and performance over time. Specifically, this study investigated how shared mental models change over time and how the changes affect team and individual performance in students manufacturing engineering teams. In this study, shared mental models were measured in terms of Team-SMM and Task-SMM. Also, each Team-SMM and Task-SMM was measured in Team-SMM Structure, Team-SMM Degree, Task-SMM Structure, and Task-SMM Degree based on Mohammed, Klimoski, and Rentsch's (2000) suggestions that shared mental models should be measured in terms of their structure and contents. The influences of Team-SMM Structure, Team-SMM Degree, Task-SMM Structure and Task-SMM Degree on team and individual performance were respectively examined per each of three time points.

The overall results are discussed with two main research questions: (1) Does SMM (Team-SMM and Task-SMM) change over time? and (2) Is Team-SMM or Task-SMM the better predictor of team and individual performance? The first research question was answered by using one-way repeated measures ANOVA. The second research question was divided into the following two research questions: (a) Does Team-SMM or Task-SMM predict team performance? If so, how well do they predict team performance over time? and (b) Does Team-SMM or Task-SMM predict individual performance? If so, how well do they predict individual performance over time? To answer these questions, random-effects GLS regression or fixed-effects regression was selectively employed based on the results of the Breusch-Pagan Lagrange Multiplier Test and the Hausman Specification Test.

The results of the study indicate that shared mental models (Team-SMM and Task-

SMM) change over time. In terms of the change in Team-SMM, the post score of Team-SMM Degree (Average) increased from Time 1 to Time 3. At the specific period from Time 1 to Time 2, the post score of Team-SMM Structure increased, but the growth score of Team-SMM Degree (Average) decreased. In terms of the change of Task-SMM, the post score of Task-SMM Degree (Average) increased from Time 1 to Time 3. In the specific time period from Time 1 to Time 2, the post score of Task-SMM Structure decreased. The post score of Task-SMM Degree (Variance) also decreased from Time 2 to Time 3. Interestingly, Team-SMM Structure increased while Task-SMM Structure decreased from Time 1 to Time 2. Moreover, the post scores of both Team-SMM Degree (Average) and Task-SMM Degree (Average), (i.e., the shared perceptions of Team-SMM and Task-SMM) increased over time, from Time 1 to Time 3. This implies that Team-SMM and Task-SMM changed at different times, and the changes also varied depending on the structure and degree of SMMs.

Second, Team-SMM and Task-SMM were associated with team and individual performance. It was assumed that Team-SMM and Task-SMM would have unique influences on team and individual performance and that their relationships would vary depending on the task and team demands during the specific time period of the team project. The results of this study supported this assumption. From Time 1 to Time 2, a highly-shared perception regarding Task-SMM (task knowledge and team environment) positively influenced the improvement of team performance, and a highly-shared perception about Team-SMM (teammate knowledge and team interaction) also led to the improvement of individual performance. From Time 2 to Time 3, team performance decreased as the variance of perception about Task-SMM (task knowledge and team environment) increased. This result implies that team members need to have a highly-shared mental model about the given task and team environment to accomplish their team project successfully. Unlike team performance, diverse perceptions of Task-SMM positively affected individual performance from Time 2 to Time 3. That is, diverse perceptions concerning task knowledge and team environment are necessary to increase individual performance at the end of the team project.

Overall, the findings of this study provided evidence that Team-SMM and Task-SMM change over time, and that they had unique influences on team and individual performance. Moreover, the unique influences varied depending on task and team demands in the specific time period of a team project. Thus, this study contributes to the efforts to reveal the underlying mechanism which explains the dynamic relationship between shared mental models and performance over time. However, many unanswered research questions remain. Future studies are expected to be conducted in the following areas. First, it will be interesting to extend this study to online team-based learning environments. Second, future research should investigate whether there is a typical mechanism that can explain the dynamic relationship between shared mental models and performance in spite of the different levels of task difficulty, different types of tasks, and different numbers of team members. Third, it is necessary to measure the accuracy of shared mental models and examine how the accuracy of shared mental models is associated with performance. Fourth, future studies should focus on making better team-based instructions based on the findings from many prior empirical studies. Ultimately, these efforts will assist students to work effectively in real workplace teams.

CHAPTER I: INTRODUCTION

Teams are important entities in various organizations. Many issues facing organizations are complex and ill-structured (Massey & Wallace, 1996). These types of issues often require teams to solve problems because teams can be more effective and efficient in dealing with tasks that are too complex or too large for an individual to undertake (Cooke, Salas, Kiekel, & Bell, 2004; Stout, Cannon-Bowers, Salas, & Milanovich, 1999). Therefore, organizations are seeking employees who have developed team skills and team process knowledge (Hackman, 1992). With the organizational need for employees to be competent in teamwork, educational institutions face the challenge of teaching and preparing students to work effectively in workplace teams. For instance, engineering colleges are being pressured by organizations not only to provide their students with intellectual development, but also to provide students with opportunities to gain teamwork experience prior to joining the organization (Adams, 2001).

In order to solve complex problems effectively, team members need to have teamwork skills such as the ability to coordinate the potentially different knowledge structures of all team members (Levine, Resnick, & Higgins, 1993). A key underlying mechanism of effective teamwork is the ability of the team to work collaboratively in the process of solving complex problems. Starks and Ericsson (2003) indicate that high performing teams utilize these problem-solving processes differently than low performing teams. While high performing teams go through complex problem-solving processes smoothly and adapt their prior problem-solving skills and strategies efficiently and effectively as needed, low performing teams are error-prone, inconsistent, and use naïve strategies.

According to Cannon-Bowers and Salas (2001), team members naturally develop a shared understanding that helps them coordinate their individual knowledge structure with those of the other team members in working through the complex problem-solving process. The notion of a coordinated shared understanding is represented as a shared mental model. The concept of a shared mental model was developed to describe team-based problem-solving processes in complex, dynamic, and ambiguous situations (Blickensderfer, Cannon-

Bowers, & Salas, 1997; Stout, 1995).

The shared mental model in teams not only has the potential to serve as a qualifier of the level of a team's problem-solving ability, but may also provide team members with valuable information during team processes that further allows for performance predictability and adaptability (Cannon-Bowers & Salas, 2001). In other words, teams that have a shared mental model can work more smoothly to respond and adapt to the needs of the team.

Having a shared mental model among team members is particularly important in manufacturing engineering education where team-based learning is an integral part of the learning environment and the learning tasks are based on complex real-world problems. Shared mental models help team members coordinate multiple perspectives for the effective solutions to given problems. According to Kozlowski, Toney, Mullins, Weissbein, Brown and Bell (2000), the shared mental model has gained importance for team performance because of the increased complexity of real-world tasks. However, not all knowledge possessed by each team member needs to be shared with the other members in order to improve team performance (Cannon-Bowers, Tannenbaum, Salas, & Volpe, 1995; Entin & Serfaty, 1999).

According to McIntyre and Salas (1995), only certain types of knowledge are dealt with in shared mental models. Mathieu, Heffner, Goodwin, Salas, and Cannon-Bowers (2000) further suggest that there are two primary shared mental models crucial to optimal team performance: the team-related shared mental model (Team-SMM) and the task-related shared mental model (Task-SMM). The Team-SMM includes an understanding of team interactions, and teammates' knowledge, skills, abilities, beliefs, preferences, and tendencies. The Task-SMM includes knowledge of typical task strategies, procedures and the team environment (Mathieu et al., 2000).

With regard to the characteristics of the shared mental model, many researchers (e.g. Cannon-Bowers et al, 2003; Klimosky et al., 1994) suggest that the shared mental models change over time. Specifically, they expected that shared mental models will increase over time through team interaction. Mathieu, Heffner, Goodwin, Salas, and Cannon-Bowers

(2000) and Levesque, Wilson, and Wholey (2001) empirically investigated the change of shared mental models over time. Mathieu, et al.(2000) found no significant change of shared mental models while Levesque, Wilson, and Wholey (2001) found that shared mental models decreased over time.

Moreover, theorists on team cognition have argued that shared mental models help team performance. However, empirical studies have produced inconsistent results about the relationships between shared mental models and team performance (Carley, 1997; HelmReich, 1997; Kraiger & Wenzel, 1997). Some researchers found significant relationships between Team-SMM and team performance, but not between Task-SMM and team performance (e.g., Leversque, Wilson and Wholey, 2001; Mathieu, Heffner, Goodwin, Salas, & Cannon-Bowers, 2000). Other studies have found that Team-SMM is less predictive of performance than Task-SMM (e.g., Mathieu, Heffner, Goodwin, Cannon-Bowers, & Salas, 2005). Moreover, Lim and Klein (2006) found that both Team-SMM and Task-SMM were significantly and positively related to team performance.

With regard to the research fields of shared mental models, most studies have been performed in military, business, sports and organizational settings. No prior studies have investigated Team-SMM and Task-SMM in a manufacturing engineering educational setting. Therefore, the focus of this study seeks to understand the relationships between shared mental models and performance in an engineering domain. A study of Team-SMM and Task-SMM in a manufacturing engineering education setting will result in a better understanding of the effects of Team-SMM and Task-SMM on team and individual performance, as well as provide insights for improving team performance in manufacturing engineering teams. Moreover, the results will hopefully inform and support engineering schools in training students to work effectively in a team and ultimately support the development of complex skills in engineering students. The following describes specific rationales for the importance of conducting this study.

There are four reasons for conducting this study. First, the main body of research on shared mental models has been primarily concerned with developing theoretical foundations (Mohammed, Klimoski, & Rentsch, 2000). Among these studies, some

researchers (e.g., Hinsz, Tindale, & Vollrath, 1997; Kraiger & Wenzel, 1997; Mohammed & Dumville, 2001) have attempted to develop a theoretical framework for the relationship between shared mental models and team performance. However, there is not yet a substantial amount of empirical evidence about the change of shared mental models and the dynamic change of relationships between shared mental models and performance over time. This study seeks to uncover how shared mental models change during the process of solving complex problems and how their effects on team and individual performance also change.

Second, many researchers assert that the shared mental models can be a predictor of team performance (McIntyre & Salas, 1995; Salas & Fiore, 2004; Smith-Jentsch, Campbell, Milanovich & Reynolds, 2001). However, there is a lack of consistent research on whether a specific type of (Team-SMM or Task-SMM) particularly affects team performance and the manner in which this may occur. Mathieu, Heffner, Goodwin, Salas, and Cannon-Bowers (2000) found a direct relationship between Team-SMM and performance. However, Resick (2004) found that team performance was the outcome of Task-SMM, but it was not related to Team-SMM. Lim and Klein (2006) empirically examined and concluded that both Team-SMM and Task-SMM predicted team performance. Therefore, this study attempts to clarify the linkages between shared mental models and team performance by examining the specific relationships between different types of shared mental models (SMMs) and performance.

Third, there is an increased awareness in many fields of the importance of shared mental models in teams. However, there have been no substantial efforts to study teams of students in educational settings (Langan-Fox, Anglim, & Wilson, 2004). In the educational setting, manufacturing engineering education deals with many complex problems and requires teams of students to work together to develop solutions to these problems. In order to understand how to improve team and individual performance in manufacturing engineering student teams, it is necessary to conduct research in the same setting. Therefore, this study was conducted using students at a manufacturing engineering school.

Fourth, there is a lack of research on the relationship between shared mental models

and individual performance. Many researchers tend to focus on the shared mental models and its effects on team performance (Griepentrog & Fleming, 2003; Kraiger & Wenzel, 1997; Rouse, Cannon-Bowers, & Salas, 1992). However, shared mental models can affect individual performance because they are interwoven with individual mental models (Cannon-Bowers, Salas, & Converse, 1993). Therefore, this study attempts to examine how shared mental models influence individual performance as well as team performance.

PURPOSE OF STUDY

The purpose of this study was to examine how Team-SMM and Task-SMM affect team and individual performance over time in student manufacturing engineering teams. Specifically, this study investigated the change in Team-SMM and Task-SMM over time and the effects of Team-SMM and Task-SMM on team and individual performance in the process of solving complex problems. Team and individual performance were expected to improve as Team-SMM and Task-SMM scores increased, and the unique effect of each Team-SMM and Task-SMM on team and individual performance was expected to vary depending on the specific time period to perform a complex project.

This study utilizes two principal indicators for the evidence of shared mental models. The first indicator includes the extent to which team members' knowledge about the team or knowledge about the task has common relationships. The second indicator of shared mental models is the degree to which team members have common perceptions of their teamwork and task work.

Measurement of the shared mental models is based on the similarity of team members' knowledge structures, specifically focusing on the relationships among the key task and team components. It is also measured by examining the similarity between team members' perceptions of the team and task. In order to carry out this research, several questions are proposed.

RESEARCH QUESTIONS

The main research questions are: how do Team-SMM and Task-SMM change over time, and how do these SMMs affect manufacturing engineering undergraduate teams' and individual students' performance? In order to answer these main research questions, there are several sub-questions that focus on two research questions.

Research Question 1: Does SMM change over time?

This research specifically investigates the change of Team-SMM and Task-SMM by addressing the following guiding questions:

1. Does Team-SMM change over time? If so, what types of changes can be found during the process of solving complex problems?
2. Does Task-SMM change over time? If so, what types of changes can be found during the process of solving complex problems?

Research Question 2: Is Team-SMM or Task-SMM a better predictor of performance at the team and/or individual level?

This research examines SMM predictability of performance by addressing the following guiding questions:

1. Does Team-SMM predict team performance? If so, how well does it predict team performance in each specific time period of a complex team project?
2. Does Team-SMM predict individual performance? If so, how well does it predict individual performance in each specific time period of a complex team project?
3. Does Task-SMM predict team performance? If so, how well does it predict team performance in each specific time period of a complex team project?
4. Does Task-SMM predict individual performance? If so, how well does it predict individual performance in each specific time period of a complex team project?

SIGNIFICANCE OF STUDY

The main goal of this study is to determine the underlying mechanism of shared mental models in teams which explains the improvement of team and individual performance. Specifically, the dynamic change of Team-SMM and Task-SMM and their timely effects on team and individual performance are investigated in complex problem-solving domains. To assist team-based learning, it is necessary to understand the mechanisms that explicate the dynamic change of Team-SMM and Task-SMM over time with regard to team and individual performance.

The significance of this study is twofold. First, information about the dynamic change of Team-SMM and Task-SMM over time is clarified. Second, this work strives to determine which one has more influence on team or individual performance and how the influential type of SMMs changes during complex problem-solving. These results will inform the future design of instruction that will lead to performance improvement. Chapter II presents the theoretical background of this study. The definition and types of shared mental models and the previous studies regarding their relationship with performance are specifically described.

CHAPTER II: THEORETICAL BACKGROUND

The emphasis of this study is on understanding the changes of shared mental models and their relationships with team and individual performance. To study these issues, it is important to share a theoretical background about shared mental models. This chapter presents the salient literature related to the current state of research associated with this study. This chapter presents a review of relevant literature in four sections. The first section discusses the theoretical background of shared mental models and related terms. In particular, the concept of the shared mental models is compared to other concepts such as team cognition, shared knowledge and shared understanding.

The second section describes two primary types of shared mental models: the team-related shared mental model (Team-SMM) and the task-related shared mental model (Task-SMM). Additionally, this section illustrates the change of Team-SMM and Task-SMM over time and their timely effects on team and individual performance.

Section three reviews previous studies on measuring shared mental models. This section provides an overview of techniques to measure shared mental models and describes the pairwise rating, questionnaires, and Pathfinder techniques that are employed for this study.

The final section of this chapter delineates important control variables that must be considered when measuring shared mental models. Within this section, three components are addressed: (1) team size, (2) task complexity, and (3) the skill levels of team members.

THEORETICAL BACKGROUND

Teams are important entities in educational as well as industrial settings. Teams create better conditions for performing complex tasks because they allow each team member to share his or her expertise, motivate one another to achieve their given task and deal with ongoing changes effectively (e.g. Burke, Stagl, Salas, Pierce & Kendall, 2006, Ilgen, Hollenbeck, Johnson & Jundt, 2005). In working as a team, team performance is not only a matter of individual cognition, but it is also supported through team cognition. Team cognition is the theoretical mechanism that illustrates cognitive processes in a team (Cooke, Kiekel, Salas, & Stout, 2003). Under the concept of team cognition, the majority of prior research has principally focused on shared mental models, shared knowledge and shared understanding (Cannon-Bowers, Salas, & Converse, 1993; Cooke et al., 2003; Gibson, 2001).

Although these concepts have been used interchangeably, each has its own definition. According to Schneider and Angelmar (1993), it is critical that future research develops strong conceptual definitions and common understandings of cognitive terminology. Thus, in an effort to clarify conceptual distinctions that have often been overlooked in the field of team research, the terms “team cognition,” “shared mental model”, “shared knowledge,” and “shared understanding” are explicated in the beginning of the theoretical background of this study.

Team Cognition

Team cognition is more than the sum of the cognition of each individual within the team (Cooke et al., 2004). It emerges from the interaction of the individual cognition of each team member and team process. Team cognition is closely related to dynamic team process involving the accumulation, interaction, examination, and accommodation of various ideas among team members (e.g. Albers, 2002; Gibson, 2001; Mohrman, 2000; Schneider & Angelmar, 1993). Teams typically follow these steps during the performance

of team projects. At the stage of accumulation, a team become aware of new information, and only selected information is operated upon by the team at the stage of interaction (Klimoski & Mohammed, 1994). In the examination stage, team members examine newly acquired information by sharing their interpretations, judgments, and opinions. At the accommodation stage, team members generate decisions and actions (Gibson, 2001). Like an individual, team members go through internalized team cognitive processes rather than automatically accepting new information without any adjustments or assimilation.

Through these processes, teams may experience cognitive conflict that can provide them with opportunities for thinking about multiple ideas (Amason & Schweiger, 1994). After verifying new information, team members integrate the information with their prior knowledge network. This cognitive conflict and knowledge integration are essential parts of team performance because team members deal with their tasks through these processes as a cognitive unit (Ensley & Pearce, 2001; Gibson, 2001). Compared to other similar concepts such as shared understanding, shared knowledge and shared mental model, team cognition is a broader concept and it focuses on the team cognitive process (MacMillan, Entin, & Serfaty, 2004).

Shared Understanding

Shared understanding is defined as a shared belief or opinion resulting from a clarification of differences in interpretation (Stahl, 2000). Clark and Brennan (1991) also define shared understanding as mutual knowledge, beliefs, and assumptions. Mulder, Swaak, and Kessels (2002) describe the process of reaching shared understanding as an important part of team learning. Each team member needs to understand new concepts related to his or her tasks and share this understanding with other team members. Through sharing personal understanding, individual thoughts converge as a shared understanding. Without an appropriate shared understanding, it will be difficult to expect team members to achieve their anticipated outcomes (Mulder et al., 2002).

Shared Knowledge

Stahl (2000) defines shared knowledge as a clear awareness generated through collaborated efforts. Further, Gibson (2001) suggests that as shared understanding is refined through the team cognitive process, it becomes shared knowledge. When team members deal with new information, it needs to be adjusted and internalized through the team's intellectual efforts (Stahl, 2000). Moreover, shared knowledge is closely and meaningfully associated with the context in which team members perform. One of the main differences between knowledge and information is that knowledge is always part of a context while information is relatively context independent (Salomon, 2000).

Many researchers who have been studying team cognition have classified shared knowledge into two categories: knowledge that is team-related and knowledge that is task-related (Cannon-Bowers, Salas, & Converse, 1993; Espinosa & Carley, 2001; Mathieu, Heffner, Goodwin, Salas, & Cannon-Bowers, 2000). Shared knowledge that is team-related refers to the extent to which team members know other team members. This includes team members' characteristics such as preferences, strengths, weaknesses and tendencies. This team-related knowledge also refers to team interactions such as interaction patterns, communication styles, and communication channels that are used to maximize performance (Cannon-Bowers et al., 1993). Knowledge that is task-related involves information closely associated with a specific task. It includes task procedures, strategies, task component relationships, and environmental constraints necessary for task performance (Cannon-Bowers & Salas, 2001; Mathieu et al, 2000). This team- and task-related shared knowledge is generated through a shared mental model in team activities.

Shared Mental Models

The term “shared mental models” is defined as a “knowledge structure held by members of a team that enables them to form accurate explanations and expectations for the 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). The shared

mental model is also described as a place where knowledge becomes more organized and structured and is stored in meaningful patterns (Bainbridge, 1991; Johnson-Laird, 1983; Rouse & Morris, 1986).

According to Johnson-Laird (1983), an individual mental model is based on the hypothesis that people organize information into patterns that reflect relationships between concepts. These patterns are stored in individual cognition, specifically in long-term memory. Whereas the individual mental model draws from individual cognition, “shared mental models” emerge from team cognition. Therefore, the shared mental model (SMM) is believed to play an important role in activating a team’s cognitive processes (Mathieu, Goodwin, Heffner, Salas, & Cannon-Bowers, 2000).

Relationships among Terms

Team cognition is the broadest concept that involves shared mental models, shared knowledge, and shared understanding. While team cognition focuses on the entire team’s cognitive processes, a shared mental model is a well-constructed cognitive structure. That is, the SMM is a team-level cognitive structure while team cognition is more closely associated with the whole process of team thinking. The dynamics of altering “shared understanding” to “shared knowledge” occur within a shared mental model and involve the processes of team cognition, which consist of accumulation, interaction, examination, and accommodation (e.g. Fiore, Salas, & Cannon-Bowers, 2001; Gibson, 2001). Over time, team members’ shared understanding becomes a more stable shared knowledge network within the shared mental model. A shared mental model is created by team members’ intellectual efforts combining into a cognitive unit.

SHARED MENTAL MODEL DEVELOPMENT FRAMEWORK

The primary concern of this section is to provide an overview of shared mental model development. More precisely, how a shared mental model is built through solving complex problems, what types of shared mental models are involved in the process, how the types of shared mental models change over time, and what relationship they have with team and individual performance are presented in this section.

A shared mental model is naturally constructed through team cognitive processes (Gutwin, & Greenberg, 2004). It is also closely related to individual mental models (Cooke, et al., 2004). Figure 2.1. depicts how individual mental models are amalgamated into a shared mental model through team interactions. Each team member (A and B) has his or her own individual mental model related to the team and the task. Team members interact, thereby confirming or sharing their individual knowledge (Gibson, 2001). This interaction results in shared knowledge that is represented as a shared mental model (SMM). Typically, the overlapping part of team members' individual mental models represents the shared mental model (SMM). This shared mental model includes shared knowledge about the team and the task. Shared knowledge about the team is represented in a team-related shared mental model (Team-SMM) while shared knowledge about the task is represented in a task-related shared mental model (Task-SMM) (Mathieu, Goodwin, Heffner, Salas, & Cannon-Bowers, 2000).

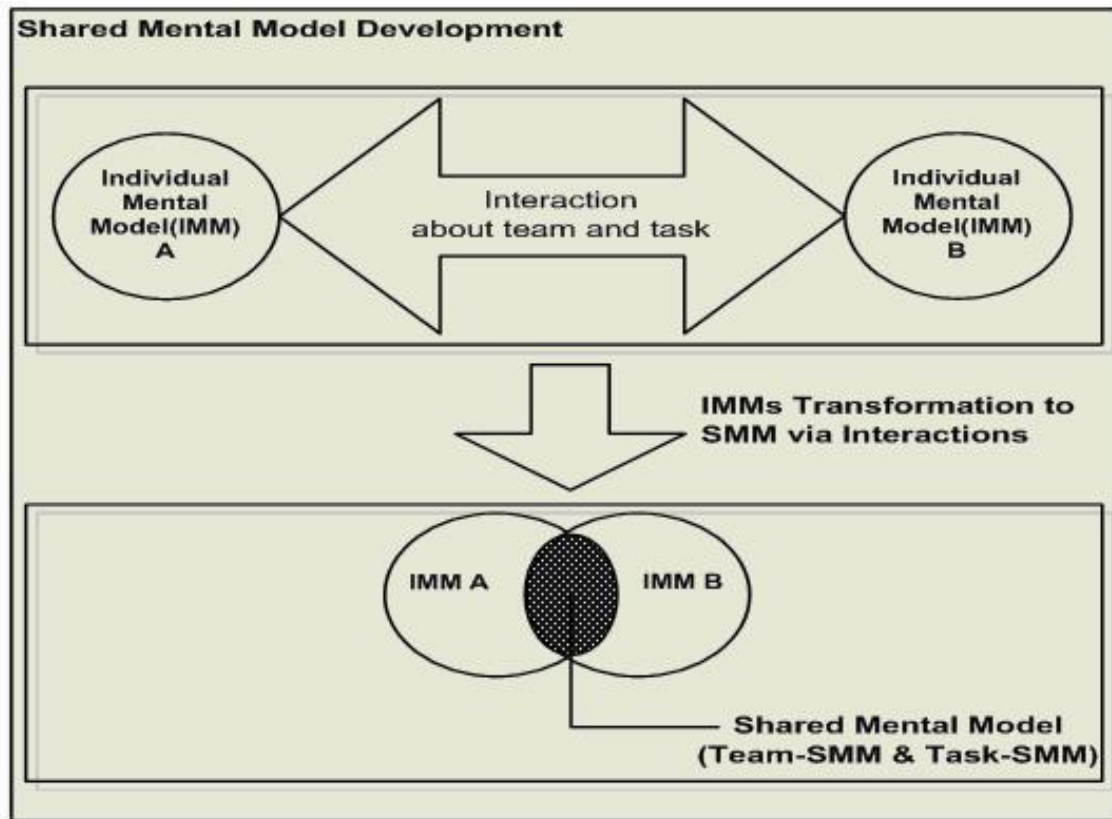


Figure 2.1. Process of Creating a Shared Mental Model

Types of Shared Mental Models

Researchers have proposed several types of shared mental models such as shared mental models about teammates' roles, team tasks, potential situations, and team interactions (Cooke, Salas, & Cannon-Bowers, 2000; Fiore, Salas, & Cannon-Bowers, 2001; Mohammed, Klimoski, & Rentsch, 2000; Salas & Fiore, 2004). However, Cannon-Bowers, Salas, and Converse (1993) classified the shared mental model into four different types that are based on the particular contents or features being shared. First, the "task mental model" includes features of the task such as strategies, procedures, environmental constraints, and contingencies. Second, the "equipment mental model" includes features regarding the functions, operations, and limitations of the team's equipment. Third, the "team interaction mental model" contains information concerning the roles, responsibilities,

communication patterns, and interactions among team members. Fourth, the “team mental model” is associated with information regarding the knowledge, skills, abilities, and behavioral tendencies of the other team members.

Based on Cannon-Bowers, Salas, and Converse’s (1993) classifications of shared mental models, Mathieu, Goodwin, Heffner, Salas, and Cannon-Bowers (2000) suggest that team-related and task-related mental models are types of shared mental models. Team-SMM includes the team interaction mental model and team mental model while the Task-SMM includes the task mental model and equipment mental model (see Figure 2.2.). These two mental models (Team-SMM and Task-SMM) are also consistent with the idea that teams develop two tracks of behavior—a teamwork track and task-work track (McIntyre & Salas, 1995).

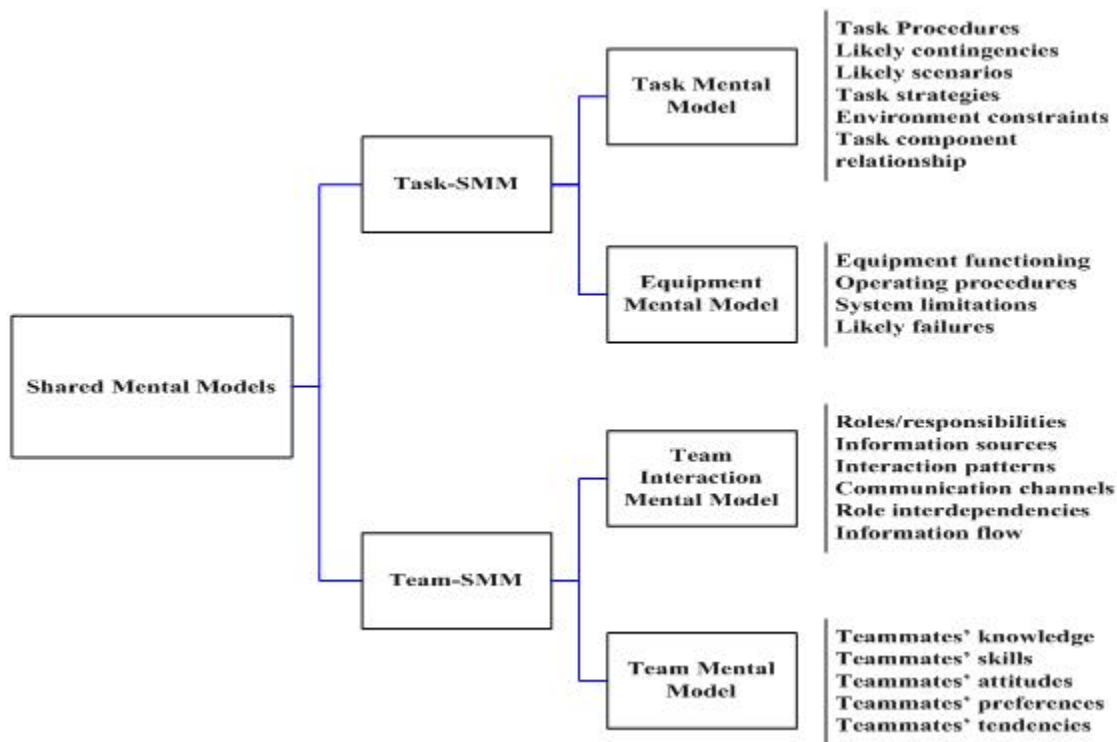


Figure 2.2. Shared Mental Models: Team-SMM and Task-SMM

Note. From “The influence of Shared Mental Models on Team Process and Team Performance” by J. E. Mathieu, T. S. Heffner, G. F. Goodwin, and E. Salas & J. A. Cannon-Bowers, 2000, *Journal of Applied Psychology*, 85, p.275. Copyright 2000 by the American Psychological Association, Adapted with permission.

While current research is not conclusive, it is generally accepted that teams who have shared mental models of both task-related and team-related knowledge have more accurate expectations of team needs, and are more able to anticipate the actions of other members (Cannon-Bowers, Salas, & Converse, 1990). Therefore, team performance may be specifically understood in terms of both Team-SMM and Task-SMM.

Evidence for positive relationships between shared mental models and performance has been reported by several authors (e.g., Carley, 1997; Heffner, 1998; Kraiger & Wenzel, 1997; Mathieu, Heffner, Goodwin, Salas, & Cannon-Bowers, 2000). Carley (1997) found that high performance teams tend to have more elaborate and widely shared mental models than low performance teams. Moreover, teams that do not share Team-SMM and Task-SMM tend to be uncoordinated, which can result in poor performance (Helmreich, 1997; Langan-Fox, Anglim, & Wilson, 2004).

However, previous studies have shown mixed findings in the relationship between shared mental models (Team-SMM and Task-SMM) and team performance. Leversque, Wilson and Wholey (2001) found that team members with highly-shared Team-SMM performed significantly better, although this relationship was not found with Task-SMM. Mathieu, Heffner, Goodwin, Salas, and Cannon-Bowers (2000) found similarity among team members' Team-SMM that was positively related to team performance. Likewise, Heffner (1998) also found that the degree of sharedness of team members' Task-SMM and Team-SMM positively influenced team processes and performance, and that team members' understanding of team processes contributed more to team effectiveness than did their understanding of the task. However, in a more recent laboratory-based study, Mathieu et al. (2005) showed that Task-SMM similarity, not Team-SMM, was significantly related to both team processes and team performance. Resick (2004) also found that team performance was the outcome of Task-SMM, but it was not related to Team-SMM. Moreover, Lim and Klein (2006) found that both Team-SMM and Task-SMM positively influenced team performance.

Based on these mixed results, it is recognized that Team-SMM and Task-SMM may not be equally effective predictors of performance. Therefore, supplemental studies are needed to obtain a better understanding about the relationships between performance and

shared mental models (Team-SMM and Task-SMM). Specifically, further research to identify where there is a change in the influence of Team-SMM or Task-SMM on team performance over time as well as whether Team-SMM or Task-SMM is the better predictor of team and individual performance is warranted.

Change of Shared Mental Models over Time

Many researchers propose that shared mental models change over time and suggest that teams go through different processes when they deal with a complex team project (e.g., Marks, Sabella, Burke, & Zaccaro, 2002; Mathieu, Heffner, Goodwin, Salas, & Cannon-Bowers, 2000; McIntyre & Salas, 1995). According to Fiore, Salas, Cuevas, and Bowers (2003), team coordination consists of three steps: (1) pre-process, (2) in-process, and (3) post-process coordination. First, pre-process coordination refers to preparatory behaviors by team members. At the stage of in-process coordination, integrated interaction occurs among the team members. Post-process coordination involves post-interaction about task performance. Different dynamics are expected depending on the coordination process (see Figure 2.3.; Fiore, Salas, Cuevas, & Bowers, 2003). For instance, building Team-SMM might be more important than Task-SMM in pre-process coordination because team members need time to get familiar with one another before getting started on their tasks. At the stage of in-process coordination, team members might need to build more robust Task-SMM than Team-SMM in order to be productive in their actual tasks.

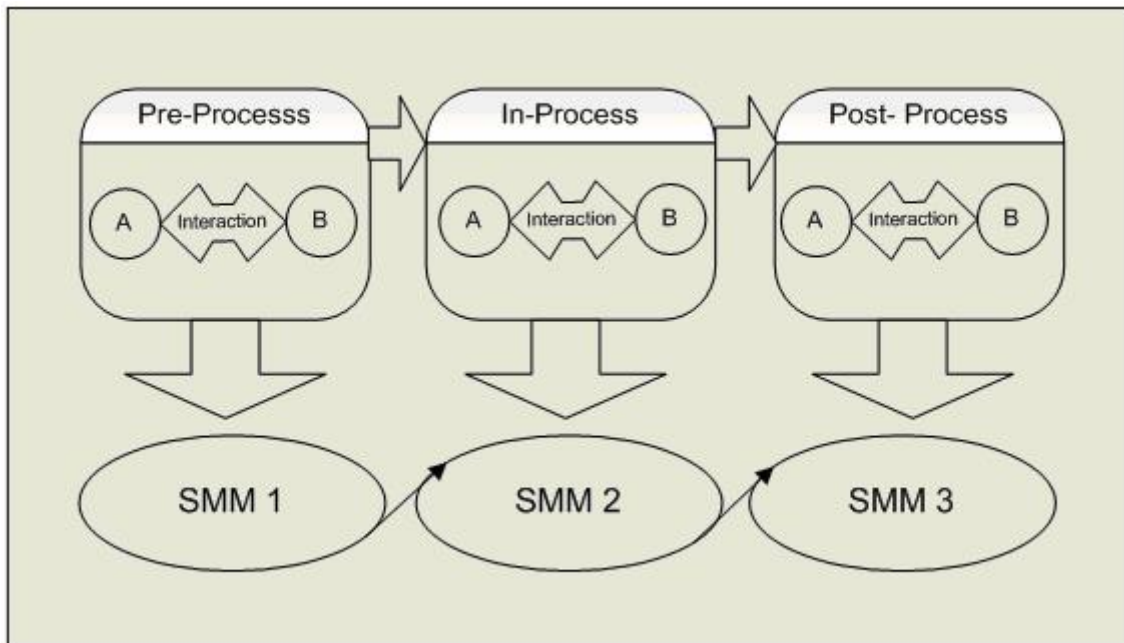


Figure 2.3. Changes of Shared Mental Models

Research about the amount and direction of change in Team-SMM and Task-SMM has shown inconsistent results. Espinosa and Carley (2001) found no overall significant increase in Team-SMM. However, they found that Team-SMM was influential in task coordination during the early stages of the task while Task-SMM increased significantly over the task period and was important in task coordination at all times. Levesque, Wilson, and Wholey (2001) also investigated the change of shared mental models, but found that their similarity actually decreased over time.

In order to provide appropriate instruction that will support team activity in educational settings, it is necessary to have a better understanding of how shared mental models change over time. In particular, it may be possible to effectively provide proper instruction at the right time in the team learning process by measuring the change of shared mental models during the team project.

MEASURING SHARED MENTAL MODELS

Regarding the measurement of shared mental models, Espinosa and Carley (2001) reviewed the current state of research in shared mental model measurement and found that there is no consensus as to which measurement is more appropriate even though substantial methodological contributions have recently been made in this area. The most common methods for measuring shared mental models have been pairwise ratings and Likert-scale questionnaires (Mohammed, Klimoski, & Rentsch, 2000) .

A distinction among different measurements can be based on whether they measure shared mental model structure (structure) or content (degree) (Mohammed, Klimoski, & Rentsch, 2000). While the shared mental model structure represents the relationship among the components of the team and the task, the content of the shared mental model indicates the degree to which team members have common perceptions of their teamwork and task work. It is usually measured by examining the similarity between team members' perceptions about the team and the task.

Measuring the structure of shared mental models can be done by representation techniques while measuring the content (degree) of a shared mental model can be done by elicitation techniques (Cooke, Salas, & Cannon-Bowers, 2000; Mohammed, Klimoski, & Rentsch, 2000). Representation techniques are used to determine the structure or the relationship of task-relevant items or team-relevant items. Specific examples are Pathfinder, multidimensional scaling programs, and card-sorting measures. On the other hand, elicitation techniques refer to the techniques that are used to determine the content of a shared mental model. Examples of elicitation techniques include interviews, questionnaires, verbal protocol analyses, and observations of task performance.

Methods for measuring shared mental models can also be classified as direct and indirect methods. Direct methods include concept maps, card sorts, repertory grids, paired comparisons (analyzed with Pathfinder, Multidimensional scaling, or UCINET), ordered trees and content analysis (Cooke, Salas, & Cannon-Bowers, 2000; Langan-Fox, Code, & Langfield-Smith, 2000). Indirect methods include self-reports, cue-contingencies, interviews, and knowledge questionnaires. According to Griepentrog and Fleming (2003),

direct measurements are better than indirect measurements because they directly capture the shared mental models of team members. However, Mohammed, Klimoski, and Rentsch (2000) suggest that researchers must ask, “Is the important variance in structure or in content? Is the content interesting in and of itself? Will the technique be used for diagnosis, training, and/or prediction purposes?” (p.155). Therefore, considering the research purpose and issues is important before choosing measurement techniques.

Variables to Consider when Measuring SMM

The shared mental model is commonly associated with diverse variables such as team size, task complexity, and the skill-levels of team members. According to Cannon-Bowers, Salas, and Converse (1993) and Kraiger and Wenzel (1997), team size, the nature of the task, and the skill levels of team members are hypothesized to affect shared mental models. Therefore, these factors should be considered in studies on shared mental models. The following sections describe how each factor can affect shared mental model development.

Team Size

Rentsch and Klimoski (2001) and Eccles and Tenenbaum (2004) recognized the importance of team size in shared mental models. In particular, Eccles and Tenenbaum (2004) explained the significant meaning of team size by the concept “coordination link (CL)” and a formula, $CL = N(N-1)/2$, where, N indicates the number of members. For example, if a team consists of three team members, there are three coordination links among them. That is, the meaning of large team size indicates that team members have many coordination links in which it will take time and effort for them to create a shared mental model. Many researchers also emphasize the importance of coordination as a key component of building shared mental models. Rentsch and Klimoski (2001) also suggested that team size would be negatively associated with shared mental models. Hence, it is necessary to consider team size when measuring shared mental models.

Task Complexity

The level of task complexity is frequently discussed in studies on shared mental models. The existing literature suggests that the level of task complexity can affect the shared mental model and team performance (Kozlowski, Toney, Mullins, Weissbein, Brown & Bell, 2000). Particularly, task complexity is related to team cognitive processing (Cooke, Kiekel, Salas, & Stout, 2003). More cognitive processing is required when dealing with a complex task than when solving a simple task. In other words, the shared mental model of a team when solving a complex problem may be different from the shared mental model of a team when solving a simple problem. This is because there are no easy solutions for complex problems. Team members should take into consideration many factors related to team-related knowledge as well as the given task itself in solving complex problems as a team. Therefore, measuring shared mental models should be conducted with consideration of the level of task complexity. An example can be found in Griepentrog and Fleming's (2003) study that measured the level of task complexity using a 3-point complexity scale asking participants if a given task was familiar to them and whether or not it was predictable.

Skill-Levels of Team Members

There is ample research evidence to show that highly-skilled team members use their shared mental models successfully and perform better than low-skilled team members (Cannon-Bowers, Salas, & Converse, 1993; Mohammed & Dumville, 2001; Smith-Jentsch, Campbell, Milanovich, & Reynolds, 2001). Highly-skilled team members selectively attend to and utilize relevant information and resources when they perform their tasks together. As team members acquire expertise over time, their shared mental models change and become more refined (Eccles & Tenenbaum, 2004; Kraiger & Wenzel, 1997; McIntyre & Salas, 1995). Therefore, the skill level of team members should be considered in conducting experimental studies because the different skill levels of team members can affect the results of measuring shared mental models.

TEAM PERFORMANCE AND INDIVIDUAL PERFORMANCE

Shared mental models are believed to contribute to both team and individual performance (Cannon-Bowers, Salas, & Converse, 1993). Shared mental models are interwoven with individual mental models that are closely associated with individual performance. While the individual's mental model reflects the individual's perception of reality (Brunswik, 1956), the shared mental model represents the team's shared perception of reality. The shared mental model is built based on team members' individual mental models. The individual mental models are also affected by the shared mental model during team projects. Therefore, it is expected that team and individual performance will depend on how well team members build their shared mental model during their team project.

According to Jeffery (1999), and Brannick and Prince (1997), the criteria for evaluating team and individual performance depends on the context of the team task. In the manufacturing engineering context, the nature of tasks is complex and dynamic (Kelley, 2005; William, Diane, & Marie, 2003). Task trends in manufacturing also show a change from an individual's linear problem-solving process to a team's complex problem-solving process (Kelley, 2005). Accordingly, an evaluation of team and individual performance should be considered through the perspective of an engineering context that deals with complex problems.

SUMMARY

In summary, the theoretical framework of shared mental models, its related terms, the primary types of shared mental models, and the change in shared mental models provides evidence for the close relationship between shared mental models, team performance, and individual performance. Presently, no practical mechanism has been established for explaining how shared mental models change and influence team and individual performance during the process of solving complex problems. This study was designed to investigate how Team-SMM and Task-SMM change over time and how their changes affect team and individual performance in the process of solving complex tasks.

CHAPTER III: METHODOLOGY

The purpose of this study is to investigate how Team-SMM and Task-SMM change over time and how these SMMs affect team and individual performance in student manufacturing engineering teams. There are two principal indicators for evidence of shared mental models. These indicators include: (1) the structure of the shared mental models in terms of team-related components (Team-SMM Structure) and task-related components (Task-SMM Structure), and (2) the degree of sharedness in shared mental models in terms of the extent to which team members have common perceptions of their teamwork (Team-SMM Degree) and task work (Task-SMM Degree). Therefore, Team-SMM Structure, Task-SMM Structure, Team-SMM Degree and Task-SMM Degree were measured and analyzed to investigate their influences on team performance and individual performance over time. This chapter will present the details on participants, team projects, instrumentation, data collection procedures, and data analysis.

PARTICIPANTS

The participants for this study were undergraduate students enrolled in an engineering class in a large public university located in the southeastern United States. Students were asked to voluntarily participate in the study as part of the class activities. Students who participated were given extra credit points for completing the study. Seventy-three undergraduate students, ranging in age from 20 to 25, participated in this study. As a result of using a real engineering class for this study, the study was conducted twice in the same course in different semesters. The course was offered every spring semester and less than 45 students usually registered for it. Therefore, 43 students in Spring 2006 and 30 students in Spring 2007 participated in the study. Even though the course description and the instructor were the same, a group equivalence test was conducted to verify group equivalence statistically. Independent samples t-tests were conducted to see if there were any differences in prior team and task experiences between the 2006 and 2007 participants.

The results showed that there were no significant differences of prior task experience scores and of prior team experience scores for the 2006 participants (Task experience score, $M = 2.54$, $SD = 0.80$; Team experience score, $M = 2.86$, $SD = 0.76$) and for the 2007 participants (Task experience score, $M = 2.78$, $SD = 0.45$; $t(58) = -1.52$, $p = .15$, Team experience score, $M = 3.01$, $SD = 0.44$; $t(60) = -1.43$, $p = .16$).

The following results of participants' demographic analysis also show that there were no significant differences between the 2006 and 2007 participants. The average age of the 2006 and 2007 participants was 22 and 21 respectively. In both groups of participants, there were more male students than female students. In 2006, 15 participants (40.5%) were female and 22 participants (59.5%) were male while nine participants (30%) were female and 21 participants (70%) were male in 2007. Also, there were more senior students than junior students in both classes. In 2006, 15% of the participants were juniors and 74 % were seniors. In 2007, 17% of the participants were juniors and 59% were seniors. Finally, significant differences were not found in the two groups of participants through 2006 to 2007; therefore, the participants were regarded as the same population.

To determine an appropriate sample size for this study, a power analysis was conducted based on Green's (1991) formula that was used in Resick's (2004) study. Green's formula calculates a sample size needed to produce a reliable prediction equation considering the estimates of effect sizes. Green's formula is $[N \geq (8 / f^2) + (m - 1)]$, where f^2 = effect size estimate and m = number of predictors. Cohen (1988) suggested using estimates of an effect size of .02, .15, or .35 for small, medium and large effects respectively. In this study, each regression equation contains eight predictors including time dummy variables and interaction variables. Therefore, $m = 8$ and $m - 1 = 7$. The desired number of teams is as follows: 30 for large effects $[(8 / .35) + (7)]$, 60 for medium effects $[(8 / .15) + (7)]$, and 807 for small effects $[(8 / .01) + (7)]$. Using this approach, the desired number of teams is at least 30 $[(8 / .35) + (3)]$ with two participants per team; therefore, a total of 60 participants would be required. Seventy-three students initially participated in this study, but three teams could not complete all the projects. As a result, a total of 67 students were recorded as the final number of participants for the study and a sample size of

33 teams was chosen to provide a conservative approach to establishing statistical power.

Each participant was randomly assigned to a team comprised of two students. The number of team members within each team was derived based on the number of roles that are necessary for completing the team project. The team project required students to work through three phases.

TEAM PROJECT

The team project consisted of a complex ill-structured problem that had multiple correct solutions. According to Albers (2002), a complex problem requires problem solvers to make diverse decisions in a real world application. It entailed highly dynamic paths beyond a step-by-step process and called for various considerations of solutions. Thus, the result could be presented as several different viable solutions.

In this study, each team was given a different manufactured product (e.g. a pinch style staple remover, water hose gun, can opener, tape measure etc.) that triggered participants' complex problem-solving processes. Even though they were given different products, the main principles that they had to use to perform their project were the same. Due to the different manufactured product given to each team, unexpected communications among teams about their given tasks could be prevented in advance. The objective of the team project was to analyze, test, and propose ways to improve their given manufactured product in terms of (1) materials, (2) manufacturing processes (including tools and fixtures), (3) designs for assembly (DFA) and disassembly (DFD), and (4) functionality and durability. Each team was also expected to perform the task as if they were working for a real manufacturing company.

The team project consisted of three phases as shown in the task analysis (Appendix A). In the first phase, each team described the given product in terms of properties and working principles. Also, teams broke down the product components and represented them in the form of an illustration. In the second phase, each team was supposed to describe each product component and identify the types of materials used to

make each product component. Additionally, teams described the manufacturing processes used to fabricate components including assembly procedures, automation, DFA, and DFD considerations. In the last phase, based on durability and functionality tests, teams identified problems with the current design, and proposed new design(s) that served to improve the given product. A detailed description of team actions and deliverables of their team project is shown in Appendix B. An industrial engineering expert intentionally created three sub-tasks that have the same level of task difficulty for this study. In addition to this, the task difficulty was also measured to confirm that the difficulty level of each task is the same. All participants were required to complete a task difficulty questionnaire that was used in Robinson's (2001) study whenever they finished each of three sub-tasks. In the questionnaire, each item was rated on a 10-point Likert scale. The specific question items were presented in the following way, from left 0, to right 9:

1. I thought this task was easy/I thought this task was hard;
2. I felt relaxed doing this task/I felt frustrated doing this task;
3. I didn't do well on this task/I did well on this task;
4. This task was not interesting/This task was interesting;
5. I don't want to do more tasks like this/ I want to do more tasks like this.

The results showed that there was no statistically significant difference in the task difficulty level among the three sub-tasks. (Phase I; $M = 5.21$, $SD = 1.14$, Phase II; $M = 5.39$, $SD = 0.98$, Phase III; $M = 5.22$, $SD = 0.94$, $t(66) = -1.41$, $p = 0.16$ between Phase I and Phase II, $t(66) = -0.12$, $p = 0.90$ between Phase I and Phase III, and $t(66) = 1.72$, $p = 0.90$ between Phase II and Phase III).

To analyze, test, and propose ways in which to improve the given product, team members were expected to go through complex problem-solving processes that include dynamic interaction, multiple revisions, elaboration, and interpretation (Albers, 2002). According to Cooke, Salas, and Cannon-Bowers (2000), shared mental models will be naturally triggered and built during the complex problem-solving process. Therefore, the

team project was employed to examine the development of a shared mental model and the effects of the shared mental model on team and individual performance.

INSTRUMENTATION

A demographic survey (Appendix C) was administered at the beginning of the team project. This survey included questions regarding participants' background information (e.g. age, gender, race, and years in school) and was also used to collect information about participants' previous task and team experiences.

In addition to the demographic survey, six instruments were used in this study. Two of the instruments were used to measure Team-SMM (one for structure and the other for degree) and two measured Task-SMM (one for structure and the other for degree). The remaining two instruments were used to measure performance: one instrument for team performance and the other for individual performance. The following sections provide a detailed description of each instrument.

Measuring Shared Mental Models

A shared mental model is defined as a “knowledge structure held by members of a team that enables them to form accurate explanations and expectations for the task, and in turn, to coordinate their actions and adapt their behavior to the demands of the task and other team members” (Cannon-Bowers, Salas, & Converse, 1993, p. 228). Principal indicators of shared mental models are: (1) the similarity of team members' knowledge structures of team and task components and (2) the degree of how closely one team member's perceptions of teamwork and task work resemble other team members' perceptions of teamwork and task work.

While the Team-SMM and Task-SMM structures were measured to examine how participants rated the relationships among the key team and task components by pairwise ratings, the degree of Team-SMM and Task-SMM was measured by questionnaires asking participants how they perceive their teamwork and task work.

Measuring Team-SMM Structure (Appendix D)

The framework for measuring Team-SMM Structure was based on Mathieu, Heffner, Goodwin, Salas, and Cannon-Bowers 's (2000) Team-SMM components. These include: (a) Role/Responsibility, (b) Information Sources, (c) Interaction Patterns, (d) Communication Channels, (e) Role Interdependencies, (f) Information Flow, (g) Teammates' Knowledge, (h) Teammates' Skill, (i) Teammates' Attitudes, (j) Teammates' Preferences, and (k) Teammates' Tendencies. The following table 3.1 shows the description of each Team-SMM Structure component.

Table 3.1.

Description of Team-SMM Structure Components

Role/Responsibility	Usual or expected function of a given team member/the tasks for which a team member is accountable
Information Sources	Place(s) (person, books, and resources) where the team can get information related to tasks
Interaction Patterns	Common communication between team members
Communication Channels	Ways (modes) that the team uses to communicate
Role Interdependencies	Relying on mutual assistance, support, cooperation, or interaction among team members' roles
Information Flow	Degree (freely vs. constrained) of information movement among team members
Teammates' Knowledge	General awareness or possession of information, facts, ideas, truths, or principles of your team members
Teammates' Skill	General team members' ability to do something well, usually gained through experience and training
Teammates' Attitudes	Team members' opinion or general feeling about something
Teammates' Preferences	Team members' views that a particular course of action is more desirable than another
Teammates' Tendencies	The way that team members typically behave or are likely to react or behave

A matrix that lists Team-SMM components along the top and side of the grid was provided to the participants to measure the Team-SMM Structure (Figure 3.1.). The relationships among the Team-SMM components was rated using a 9-point scale that ranges from “-4” (negatively related, a high degree of one requires a low degree of the other) to “+ 4” (positively related, a high degree of one requires a high degree of the other).

The specific Team-SMM Structure matrix for Phase I, Phase II, and Phase III is shown in Appendix D. An example for measuring the Team-SMM Structure is shown in Figure 3.1.

	-4	-3	-2	-1	0	1	2	3	4	
	Negatively Related: A high degree of one requires a low degree of the other. Having a lot of one means you must have very little of the other				Totally unrelated				Positively Related: A high degree of one requires a high degree of the other. Having a lot of one means you must have a lot of other as well	
	Information Sources	Interaction Patterns	Communication Channels	Role Interdependencies	Information Flow	Teammates' Knowledge	Teammates' Skill	Teammates' Attitudes	Teammates' Preferences	Teammates' Tendencies
Role/ Responsibility	Information Sources									
	Interaction Patterns	Communication Channels								
		Role Interdependencies								
			Information Flow							
				Teammates' Knowledge						
					Teammates' Skill					
						Teammates' Attitudes				
							Teammates' Preferences			

Figure 3.1. Example for Measuring the Structure of Shared Mental Models

Measuring Team-SMM Degree (Appendix E)

The agreement of the degree of Team-SMM was measured by a questionnaire (e.g. Blickensderfer, Cannon-Bowers, & Salas, 1999; Levesque, Wilson, & Wholey, 2001; Rentsch, McNeese, Pape, Burnett, Menard, & Anesgart, 1998) that asked participants how they perceived the degree of their teamwork. This questionnaire was used to measure the

level of how closely one team member's perceptions of teamwork resembled other team members' perceptions of teamwork.

The Team-SMM questionnaire (Appendix E) was created based on Johnson, Lee, Lee, O'Connor, Khalil, Huang, and Brown's (2007) study of shared mental models and Jeffery's (1999) perceived team performance instrument. The reliability of Jeffery's (1999) instrument was .884 (Cronbach's Alpha) when the instrument was used in a pilot study (Lee, Johnson, O'Connor, Khalil, Lee, & Huang, 2005).

According to Mathieu, Heffner, Goodwin, Salas, and Cannon-Bowers (2000), Team-SMM is composed of teammate knowledge and team interaction. Thus, the Team-SMM Degree questionnaire consists of measuring these two concepts. The concepts of teammate knowledge and team interaction were measured by nine questionnaire items and 16 questionnaire items respectively on a 5-point Likert scale ranging from 1 "strongly disagree" to 5 "strongly agree." These include: "My teammate has a general knowledge of specific team tasks," "My teammate knows specific strategies for completing various tasks," "My team communicates with other teammates while performing team tasks," "My team can adopt flexibly any roles within my team," etc.

The Team-SMM Degree instruments were administered before teams began to work on their task (Pre-Phase I), between each phase (Between Phase I & II, and Between Phase II & III) and post-task completion (Post-Phase III). The reliability estimates (Cronbach's alpha) of the Team-SMM Degree questionnaire on (1) Pre-Phase I, (2) Between Phase I & II, (3) Between Phase II & III, and (4) Post-Phase III were .995, .982, .981, and .978, respectively.

Measuring Task-SMM Structure (Appendices F, G, H)

To measure Task-SMM Structure, a task analysis (Appendix A) was conducted in order to determine the main components of the team project. Two researchers who are familiar with the study hypotheses and one expert who is familiar with the engineering project performed the task analysis. In order to logistically collect the data, three sets of inventories of the important task components associated with completing the three sub-

tasks were formed. According to Royer, Cisero, and Carlo (1993), people are not able to sustain concentration in conducting pairwise ratings over a maximum of 15 to 20 concepts. Thus, less than 15 task components were selected. In particular, six, nine, and 10 task components were accordingly selected as key behaviors. These grouping were then translated into three sub-tasks: Phase I, Phase II, and Phase III (see Table 3.2.)

Table 3. 2.

Task-SMM Structure Components for each Team Project Phase

Phase I	Phase II	Phase III
Familiarization with product function and properties	Determine product manufacturing	Identify points of improvement
Describe product function	Determine materials composition for each of the components	Performing analysis on product criteria
Determine required product properties	Determine manufacturing processes used to create individual piece	Identify potential solutions
Analyze product components	Determine assembly challenges	Determine product optimization solution details
Measure components	Test product functionality and performance	Assess overall product
Convert component data into Mechanical drawing	Perform durability tests and Determine product life cycle	Validate/justify product Optimization solution details
	Determine tooling techniques used	Identify problems/issues
	Figure out how the components were assembled into the product	Identify solution details
	Test various functions and features of the product	Modify solutions details until reached desired state
		Determine product goals

Based on the task components in Table 3.2., three types of Task-SMM Structure measures were created for each phase. Like the Team-SMM Structure measure, the Task-SMM Structure measure was conducted by asking participants to judge the relatedness of task components associated with the three phases of their team project. Namely, participants rated the listed task components along the top and side of the grid using a 9-point scale that ranges from “-4” (negatively related, a high degree of one requires a low degree of the

other) to “+ 4” (positively related, a high degree of one requires a high degree of the other). Appendix F, G, and H illustrates the Task-SMM Structure measure for Phase I, Phase II, and Phase III respectively.

Measuring Task-SMM Degree (Appendices I, J, K, L)

The Task-SMM Degree questionnaire was used to measure the level at which team members had common perceptions of task work. Specifically, the similarity between one team member’s perceptions of task and other team members’ perceptions of task was examined by the Task-SMM Degree questionnaire. According to Mathieu, Heffner, Goodwin, Salas, and Cannon-Bowers (2000), Task-SMM consists of task knowledge and team environment. Therefore, the Task-SMM Degree questionnaire included items to measure these two components.

The nine items for measuring team environment were selected based on Johnson, Lee, Lee, O’Connor, Khalil, & Huang ’s (2007) study. For items measuring team environment, the factor loadings were $>.4$ and the reliability of the measurement was .85 (Cronbach’s Alpha). The Task-SMM Degree questionnaire measured task knowledge and contained four items in Phase I, six items in Phase II, and seven items in Phase III. The different number of questionnaire items was derived from the different number of task components for each phase. Each item in the questionnaire had a 5-point Likert scale ranging from 1 “strongly disagree” to 5 “strongly agree.”

Task-SMM Degree instruments were administered before teams began to work on their task, between each phase, and post-task completion. Appendix I (Pre-Phase I), Appendix J (Between Phase I and Phase II), Appendix K (Between Phase II and Phase III), and Appendix L (Post-Phase III) contain the Task-SMM Degree questionnaire to measure team members’ perceptions of task knowledge and team environment in Phase I, Phase II, and Phase III. The reliability estimates (Cronbach’s alpha) of the Task-SMM Degree questionnaire on (1) Pre-Phase I, (2) Between Phase I & II, (3) Between Phase II & III, and (4) Post-Phase III were .982, .980, .876 and .941, respectively.

Measuring Performance

In this study, team performance (TP) and individual performance (IP) were measured as dependent variables. The following sections describe how each type of performance was measured.

Measuring Team Performance (Appendix M)

Measuring team performance was based on students' team reports that were submitted at the end of each of the three sub-tasks. A modified version of the MET (Manufacturing Engineering Technology) criteria, validated in Nelson's (1994) study, was used to evaluate the team reports (Appendix M). The average of team scores evaluated by two raters was counted as each team's team performance score. To obtain the reliability of this method, inter-rater reliability was assessed by Kappa statistic for each team performance measure. The obtained inter-rater reliabilities showed 0.71, 0.75 and 0.73 agreements¹ in Phase I, Phase II and Phase III respectively. A Kappa value of more than 0.60 was considered to be a substantial agreement (Landis & Koch, 1977).

Measuring Individual Performance (Appendices N, O, P)

Individual performance was measured by a questionnaire that had five short-answer questions (e.g., "Which part do you think has the highest material cost?", "What type of test would you perform to assess the durability of the product under service conditions?", "Describe the step-by-step manufacturing processes"). Three different sets of questions were provided to the participants at the end of each of the three sub-tasks. Appendices N, O, and P include the individual performance measures for the team project in Phase I, Phase II, and Phase III respectively. The individual performance scores were also evaluated by two raters. The average of their scores was counted as the individual performance score. The inter-rater reliability was assessed by Kappa statistic. The results of

¹ Poor agreement = Less than 0.20, Fair agreement = 0.20 to 0.40, Moderate agreement = 0.40 to 0.60, Substantial agreement = 0.60 to 0.80, Almost perfect agreement = 0.80 to 1.00 (Landis & Koch, 1977)

the Kappa statistic showed the 0.74, 0.75 and 0.75 agreement of two raters in Phase I, Phase II and Phase III respectively. Because more than 0.60 was considered to be a substantial agreement (Landis & Koch, 1977), the individual performance scores were used for this study.

DATA COLLECTION PROCEDURES

With permission of the course instructor, two researchers introduced themselves and briefly explained the purpose of the study and the students' potential benefits from participation. Subsequently, an informed consent form was distributed and collected. The consent form informed students of the purpose of the study, the total time commitment, and the benefits of study participation. The consent form also advised that participation was voluntary and that students may stop participation at anytime without penalty or loss of benefits.

After collecting the forms, the participants were randomly assigned to two-person teams and informed that they would be given a complex problem to solve as a team during the next three-week period. Also, participants were informed that they should carry out the team project as if they were working in a manufacturing company as a manager or design engineer.

Research data was collected four times. During the first data collection session, researchers explained how to complete the Team-SMM Structure matrix instrument, the Team-SMM Degree questionnaire, the Task-SMM Structure matrix instrument, and the Task-SMM Degree questionnaire. Researchers informed participants of the anticipated time it would take to complete all instruments.

Team-SMM Data Collection

The same Team-SMM Structure and Team-SMM Degree instruments were provided to participants at Pre-Phase I (Time Point 1), Between Phase I & II (Time Point 2), Between Phase II & III (Time Point 3), and Post-Phase III (Time Point 4) as shown in

Figure 3.2.

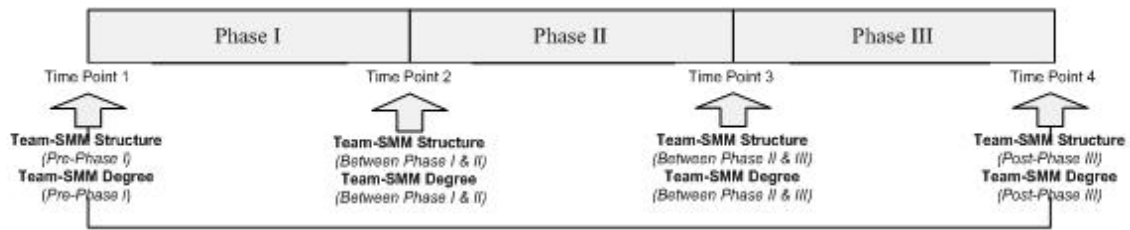


Figure 3.2. Team-SMM Structure and Team-SMM Degree Data Collection Procedure

Task-SMM Data Collection

The Task-SMM instruments were implemented for measuring Task-SMM Structure. The three unique Task-SMM Structure instruments included (1) Phase I (administered two times, both pre and post phase), (2) Phase II, (administered two times, both pre and post phase), and (3) Phase III, (administered two times, both pre and post phase).

Four instruments were used to measure the degree of Task-SMM. These instruments consisted of (1) Pre-Phase I, (2) Between Phase I & II, (3) Between Phase II & III, and (4) Post-Phase III. Instruments measuring Task-SMM Degree were administered with other instruments at Time Points 1 through 4 (Figure 3.3).

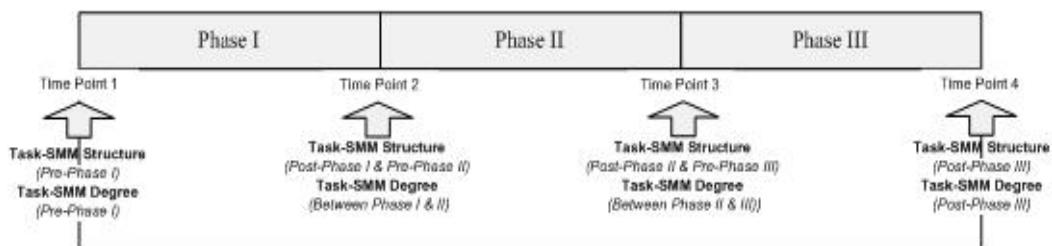


Figure 3.3. Task-SMM Structure and Task-SMM Degree Data Collection Procedure

Performance Data Collection

The performance data collection took place when participants completed their team project on each phase as shown in Figure 3.4. Team performance was measured by

each team's report that was submitted at the end of each phase. Individual performance was measured with five short-answer questions per Phase I, Phase II, and Phase III (15 questions total).

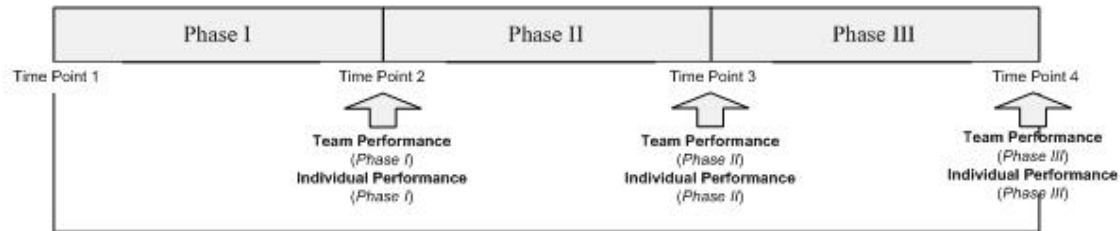


Figure 3.4. Team and Individual Performance Data Collection Procedures

In sum, the general formats of Team-SMM instruments and Task-SMM instruments were the same. However, the task components in Task-SMM Structure and the questionnaire items in Task-SMM Degree were different for the three phases. Additionally, team performance and individual performance measures were conducted after participants completed each of the three sub-tasks of their team project.

DATA ANALYSIS

After the data had been collected, data analysis was carried out in two phases. The first phase involved converting the raw data into similarity scores. The second phase consisted of analyzing the changes of SMMs and their relationship with performance.

In the first phase, data from the Team-SMM Structure and Task-SMM Structure instruments was converted into similarity scores using pathfinder networks (PFNets). The PFNets program is often used to measure the similarity of pairwise comparison ratings (e.g. Goldsmith, Johnson, & Acton, 1991; Jeffery, 1999; Marks, Sabella, Burke, & Zaccaro, 2002; Schvaneveldt, 1990; Stout, Cannon-Bowers, Salas, & Milanovich, 1999). Specifically, the Pathfinder output was used as a score to represent the similarity of two team members' ratings on Team-SMM Structure and Task-SMM Structure. The similarity score ranges from 0, no similarity, to 1, complete similarity. As an example, a score of 0.3 would mean that 30% of the structure of the shared mental model among team members is shared. The

average similarity scores of all team members' Team-SMM Structure and Task-SMM Structure were respectively calculated. Pretest and post-test similarity scores were calculated per Phase I, Phase II, and Phase III.

Also in the first phase, data collected from Team-SMM Degree and Task-SMM Degree instruments were put into an Excel spreadsheet to calculate a similarity score (standard deviation and average scores between team members' ratings for each item).

Similarity Score Analysis

The second analysis phase consisted of analyzing the changes of SMMs and their relationship with performance. In this section, research questions and hypotheses for this study were restated and data analyses were presented. The main research question for this study is: How do shared mental models affect team and individual performance on complex problem-solving tasks related to product manufacturing with undergraduate engineering students? There are two guiding questions in this study: (1) Does SMM change over time? and (2) Is Team-SMM or Task-SMM a better predictor of performance over time?

Guiding Question 1—Does SMM change over time?

This study specifically investigated the change of Team-SMM and Task-SMM over time by addressing the following research questions.

1. Does Team-SMM change over time? If so, how does it change?

Theoretical Hypothesis 1.1

- 1.1.1. Team-SMM Structure will become more similar over time.
- 1.1.2. Perceptions about Team-SMM Degree will become more similar over time.

Operational Hypothesis 1.1

- 1.1.1. Team-SMM Structure similarity scores calculated by the Pathfinder program will increase over time
- 1.1.2. The variance (standard deviation) of the perception ratings about Team-SMM Degree will get closer (decrease) over time.
- 1.1.3. The average score of the perception ratings about Team-SMM Degree will

increase over time.

2. Does Task-SMM change over time? If so, how does it change?

Theoretical hypothesis 2.1

2.1.1. Task-SMM Structure will become more similar over time.

2.1.2. Perceptions about Task-SMM Degree will become more similar over time.

Operational hypothesis 2.1

2.1.1. Task-SMM Structure similarity scores produced by the Pathfinder program will increase over time.

2.1.2. The variance (standard deviation) of the perception ratings about the Task-SMM Degree will get closer (decrease) over time.

2.1.3. The average score of perception ratings about the Task-SMM Degree will increase over time.

Data Analysis: One-way repeated measures ANOVA was conducted to examine the change of Team-SMM Structure, Team-SMM Degree, Task-SMM Structure and Task-SMM Degree over time. If there was any significant difference, post hoc analysis was conducted.

Guiding Question 2—Is Team-SMM or Task-SMM the better predictor of performance?

This study specifically investigated whether Team-SMM or Task-SMM is the better predictor of team and/or individual performance. Research questions include:

3. Does Team-SMM or Task-SMM predict team performance? If so, how well do they predict team performance over time?

Theoretical hypothesis 3.1

3.1.1. As Team-SMM or Task-SMM increases, team performance will increase.

Operational hypothesis 3.1

3.1.1. As the similarity score on Team-SMM Structure or Task-SMM Structure increases, the team performance score will show a statistically significant increase.

Operational hypothesis 3.2

- 3.2.1. As the variance (standard deviation) of the perception ratings about Team-SMM Degree or Task-SMM Degree decreases, the team performance score will show a statistically significant increase.
 - 3.2.2 As the average score of the perception ratings about Team-SMM Degree or Task-SMM Degree increases, the team performance score will show a statistically significant increase.
4. Does Team-SMM or Task-SMM predict individual performance? If so, how well do they predict individual performance over time?

Theoretical hypothesis 4.1

- 4.1.1. As Team-SMM or Task-SMM increases, individual performance will increase.

Operational hypothesis 4.1

- 4.1.1. As the similarity score on Team-SMM Structure or Task-SMM Structure increases, the individual performance score will show a statistically significant increase.

Operational hypothesis 4.2

- 4.2.1. As the variance (standard deviation) of the perception ratings about the Team-SMM Degree or Task-SMM Degree decreases, the individual performance score will show a statistically significant increase.
- 4.2.2. As the average score of the perception ratings about Team-SMM Degree or Task-SMM Degree increases, the individual performance score will show a statistically significant increase.

Data Analysis: Random-effects GLS (Generalized Least Squares) regression or fixed-effects regression was selectively used to examine these hypotheses. The results of this analysis showed how much the change of dependent variables (i.e., team performance and individual performance) was explained by the change of independent variables (i.e., Team-SMM Structure, Team-SMM Degree, Task-SMM Structure and Task-SMM Degree) over time. The STATA 8.0 SE statistical package was used to carry out the random-effects

GLS regression and fixed-effects regression.

CHAPTER IV: RESULTS

INTRODUCTION

This study investigated the change of shared mental models in terms of Team-SMM and Task-SMM and the effects of Team-SMM and Task-SMM on team and individual performance. Twelve operational hypotheses were formulated to answer the following main research questions: (a) Does Team-SMM change over time? If so, how does it change?, (b) Does Task-SMM change over time? If so, how does it change?, (c) Does Team-SMM or Task-SMM predict team performance? If so, how well do they predict team performance over time?, and (d) Does Team-SMM or Task-SMM predict individual performance? If so, how well do they predict individual performance over time?

This chapter consists of three sections. First, the overall descriptive data was analyzed and is presented. Second, the results of one-way repeated measures ANOVA to see the change of shared mental models are described. Third, the results of random-effects GLS regression or fixed-effects regression to examine the relationship between shared mental models and performance are presented. At the end of each main result of the analyses, a brief summary of the results are also provided.

Descriptive Data

The descriptive statistics for team performance, individual performance, Team-SMM related variables, and Task-SMM variables are presented in the following Table 4.1.

Table 4.1.

Means and SDs for Team Performance, Individual Performance, Team-SMM related Variables and Task-SMM related Variables

Variables			Phase I		Phase II		Phase III		
			<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	
Team Performance ^a			14.20	2.93	17.92	2.48	21.52	2.43	
Individual Performance ^b			47.30	11.33	50.77	17.58	56.66	21.10	
Team-SMM	Pre Score	Degree (Variance) ^c	0.84	0.64	0.68	0.44	0.59	0.43	
		Degree (Average) ^d	2.48	0.99	3.65	0.64	3.98	0.51	
		Structure ^e	28.91	12.96	26.88	8.44	33.79	15.17	
	Post Score	Degree (Variance) ^f	0.68	0.44	0.59	0.43	0.59	0.45	
		Degree (Average) ^g	3.65	0.64	3.98	0.51	4.11	0.45	
		Structure ^h	26.88	8.44	33.79	15.17	32.85	15.26	
	Growth Score	Degree (Variance) ⁱ	-0.16	0.78	-0.10	0.41	.004	0.35	
		Degree(Average) ^j	1.19	0.97	0.32	0.72	0.13	0.36	
		Structure ^k	-2.03	10.77	6.91	13.40	-0.94	18.23	
	Task-SMM	Pre Score	Degree (Variance) ^l	0.88	0.54	0.75	0.38	0.79	0.42
			Degree (Average) ^m	2.73	0.93	3.19	0.82	3.30	0.91
			Structure ⁿ	42.45	19.36	31.58	12.33	34.64	16.07
Post Score		Degree (Variance) ^o	0.71	0.45	0.63	0.32	0.42	0.37	
		Degree (Average) ^p	3.37	0.86	3.69	0.33	4.44	0.38	
		Structure ^q	46.45	15.13	32.85	14.37	35.91	15.35	
Growth Score		Degree (Variance) ^r	-0.16	0.60	-0.12	0.35	-0.37	0.41	
		Degree (Average) ^s	0.62	1.35	0.50	0.74	1.16	1.16	
		Structure ^t	4.00	22.94	1.27	18.53	1.27	13.69	

Notes:

- a. The range of possible scores for team performance is from 5 to 25
- b. The range of possible scores for individual performance is from 0 to 100
- c. Standard Deviation scores of Team-SMM Degree at pretest per each phase
- d. Mean of Team-SMM Degree at pretest per each phase
- e. Similarity scores which were calculated by Pathfinder at pretest per each phase
- f. Standard Deviation scores of Team-SMM Degree at post test per each phase
- g. Mean scores of Team-SMM Degree at post test per each phase
- h. Similarity scores which were calculated by Pathfinder at post test per each phase
- i. The Gain score between Standard Deviation scores of Team-SMM Degree at pretest and Standard Deviation scores of Team-SMM Degree at post test per each phase

- j. The Gain score between mean scores of Team-SMM Degree at pretest and mean scores of Team-SMM Degree at post test per each phase
- k. The Gain score between the similarity scores of Team-SMM Structure at pretest and the similarity scores of Team-SMM Structure at post test per each Phase
- l. Standard Deviation scores of Task-SMM Degree at pretest per each phase
- m. Mean scores of Task-SMM Degree at pretest per each phase
- n. Similarity scores which were calculated by Pathfinder at pretest per each phase
- o. Standard Deviation scores of Task-SMM Degree at post test per each phase
- p. Mean scores of Task-SMM Degree at post test per each phase
- q. Similarity scores which were calculated by Pathfinder at post test per each phase
- r. The Gain score between Standard Deviation scores of Task-SMM Degree at pretest and Standard Deviation scores of Task-SMM Degree at post test per each phase
- s. The Gain score between mean scores of Task-SMM Degree at pretest and mean scores of Task-SMM Degree at post test per each phase
- t. The Gain score between similarity scores of Task-SMM Structure at pretest and similarity scores of Task-SMM Structure at post test per each phase

The frequency distributions of the team performance and individual performance including all three time measures were approximately shaped as a normal curve as depicted in Figure 4.1.

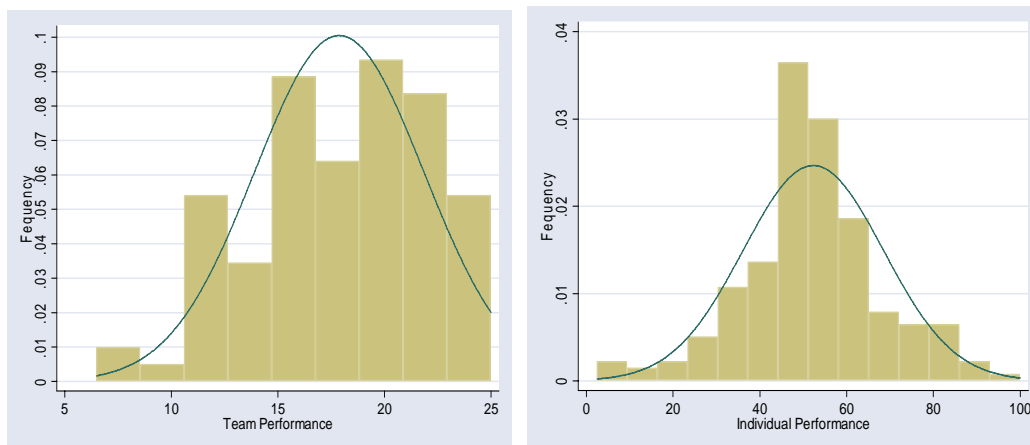


Figure 4.1. Frequency distributions of the overall team performance score and individual performance score

The general tendency of growth of team performance and individual performance were investigated through a graphical presentation. Figure 4.2. was constructed considering the time variable.

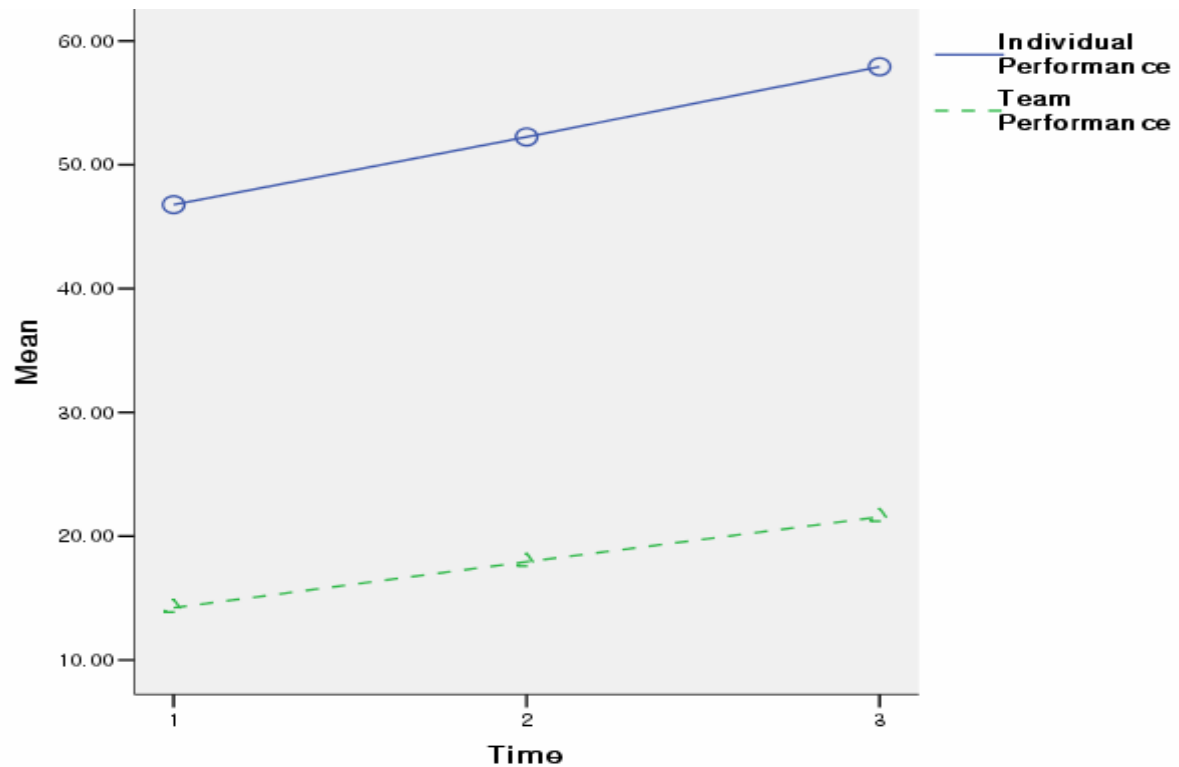


Figure 4.2. Line Plot of the Relationship between Time and Performance.

As shown in Figure 4.2., team and individual performance scores gradually increased over time.

The following parts present the results of the change of shared mental models in terms of Team-SMM and Task-SMM and whether Team-SMM or Task-SMM has a more positive relationship with team and individual performance over time. Team-SMM and Task-SMM were expected to increase over time and have unique effects on team and individual performance in the specific time period of the team project. The summary of the results was also provided at the end of each guiding question (1st Guiding Question; Does the shared mental model change over time? and 2nd Guiding Question; Does Team-SMM or Task-SMM predict team and individual performance? If so, how well do they predict team and individual performance over time?).

Change of Shared Mental Models

One of the guiding questions in this study was to examine the change of shared mental models. In order to determine the change of Team-SMM and Task-SMM, one-way repeated measures ANOVA was performed. Also, the changes were examined with the post score and growth score of Team-SMM and Task-SMM that were collected at each of the three phases. The specific results were described corresponding to the operational hypotheses.

Change of Team-SMM Structure and Team-SMM Degree over time

Operational Hypothesis 1.1.1

1.1.1. Team-SMM Structure similarity scores calculated by the Pathfinder program will increase over time

Change of Post Score in Team-SMM Structure Similarity

One-way repeated measures ANOVA was conducted to compare the scores of the Team-SMM Structure at Time 1, Time 2, and Time 3. The means and standard deviations are presented in Table 4.2. The results show that the Team-SMM Structure similarity scores significantly increased over time, $F(2, 64) = 3.50, p < 0.05$. A paired-samples t-test was conducted to examine the specific time period when the post score in Team-SMM Structure changed. The results showed that there was a statistically significant increase in the scores from Time 1 ($M = 26.88, SD = 8.44$) to Time 2 ($M = 33.79, SD = 15.17$), $t(32) = -2.96, p < 0.01$. However, there was no significant change from Time 2 ($M = 33.79, SD = 15.17$) to Time 3 ($M = 32.85, SD = 15.26$), $t(32) = 0.30, p = 0.77$

Table 4.2.

Means and SDs of Post Score in Team-SMM Structure

Time Period	<i>k</i>	<i>M</i>	<i>SD</i>
Time 1	33	26.88	8.44
Time 2	33	33.79	15.17
Time 3	33	32.85	15.26

k= no. of teams

Change of Growth Score in Team-SMM Structure Similarity

The results of one-way repeated measures ANOVA show that there was no significant change of growth score in Team-SMM Structure similarity. The means and standard deviations of growth score in Team-SMM Structure are presented in Table 4.3. Mauchly's test indicated that the assumption of sphericity had been violated ($\chi^2(2) = 7.77$, $p < 0.05$); therefore the degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity ($\epsilon = 0.82$). The results showed that there was no significant change of the growth score in Team-SMM Structure over time, $F(1.64, 52.39) = 3.07$, $p = 0.065$.

Table 4.3.

Means and SDs of Growth Score in Team-SMM Structure

Time Period	<i>k</i>	<i>M</i>	<i>SD</i>
Time 1	33	-2.03	10.77
Time 2	33	6.91	13.40
Time 3	33	-0.94	18.23

k= no. of teams

The following Figure 4.3. shows the graphic representation of the changes of both post score and growth score in Team-SMM Structure.

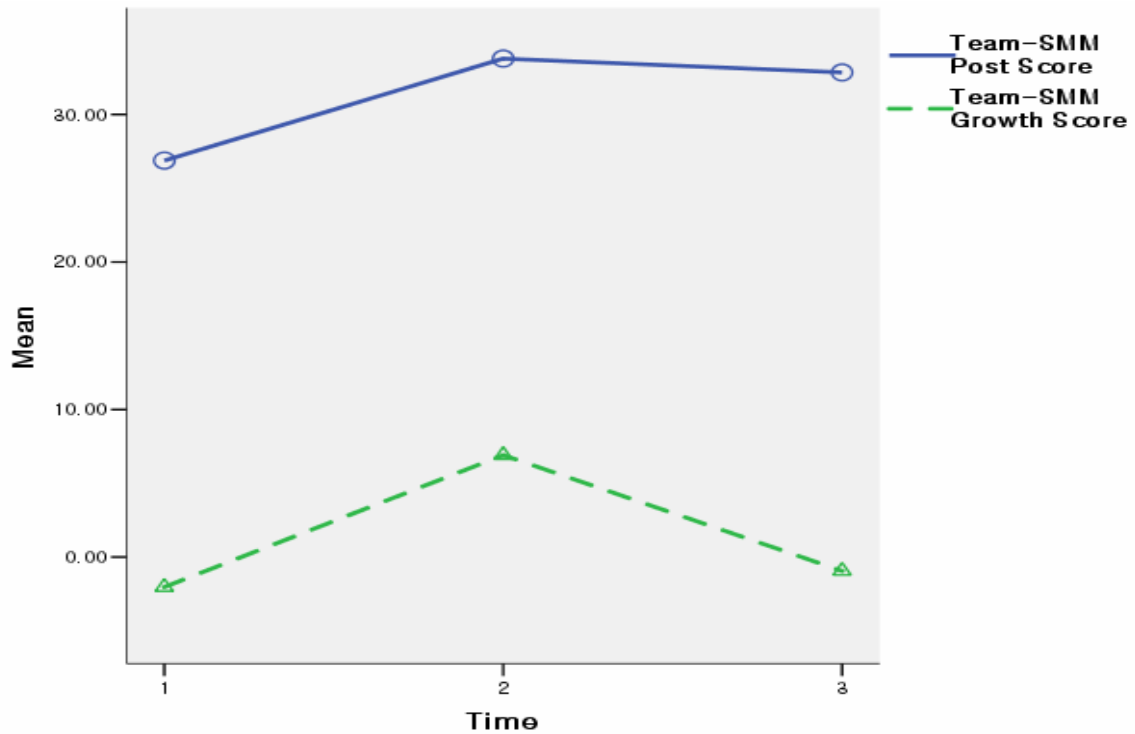


Figure 4.3. Changes of Post Score and Growth Score in Team-SMM Structure

As shown in Figure 4.3, the post score in Team-SMM Structure similarity was about 26.88 % at the base line. The similarity score significantly increased from the beginning of the team project to the middle of the project and a little bit decreased at the end of the project. Even though the growth score of Team-SMM Structure was not statistically significant, the growth score of Team-SMM Structure increased from Time 1 to Time 2 and decreased from Time 2 to Time 3. This result implies that team members increased the similarity of Team-SMM that consisted of teammate knowledge and team interaction information from the beginning of their project to the middle of their project. In addition, their sharedness gradually decreased from the middle of the project to the end.

Operational Hypothesis 1.1.2.

1.1.2. The variance (standard deviation) of the perception ratings about the Team-SMM Degree will get closer (decrease) over time.

The change of the team members' perceptions of Team-SMM was examined with the standard deviation score and average score of participants' ratings on Team-SMM Degree questionnaires. Also, each post score and growth score of their ratings that was collected at each of the three phases was specifically used to see the change in their perceptions about Team-SMM. The following shows the results of testing the operational hypothesis 1.1.2.

Change of Post Score in Team-SMM Degree (Variance)

To investigate the change of team members' perceptions about Team-SMM over time, one-way repeated measure ANOVA was performed to compare the variance (standard deviation) scores on the Team-SMM at Time 1, Time 2, and Time 3. It was expected that the variance (standard deviation) scores would decrease over time. However, the results showed that the Team-SMM Degree (Variance) was not significantly affected by time $F(2, 64) = 1.32, p = 0.27$. The results are presented in Table 4.4.

Table 4.4.

Means and SDs of Post Score in Team-SMM Degree (Variance)

Time Period	<i>k</i>	<i>M</i>	<i>SD</i>
Time 1	33	0.68	0.44
Time 2	33	0.59	0.43
Time 3	33	0.59	0.45

k= no. of teams

Change of Growth Score in Team-SMM Degree (Variance)

Operational hypothesis 2.1.1. was also tested with the growth score of Team-SMM

Degree(Variance). One-way repeated measures ANOVA was also conducted to examine the change of the growth score in Team-SMM Degree (Variance) over time. The means and standard deviations are presented in Table 4.5. Mauchly's test indicated that the assumption of sphericity had been violated ($\chi^2(2) = 6.98, p < 0.05$); therefore, degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity ($\epsilon = 0.83$). The results showed that there was no significant change of the growth score in Team-SMM Degree (Variance) over time $F(1.66, 53.26) = 0.65, p = 0.499$.

Table 4.5.

Means and SDs for Growth Score in Team-SMM Degree (Variance)

Time Period	<i>k</i>	<i>M</i>	<i>SD</i>
Time 1	33	-0.16	0.78
Time 2	33	-0.10	0.41
Time 3	33	0.004	0.35

k= no. of teams

The following Figure 4.4. shows the graphical representation of the change of post score and growth score in Team-SMM Degree (Variance).

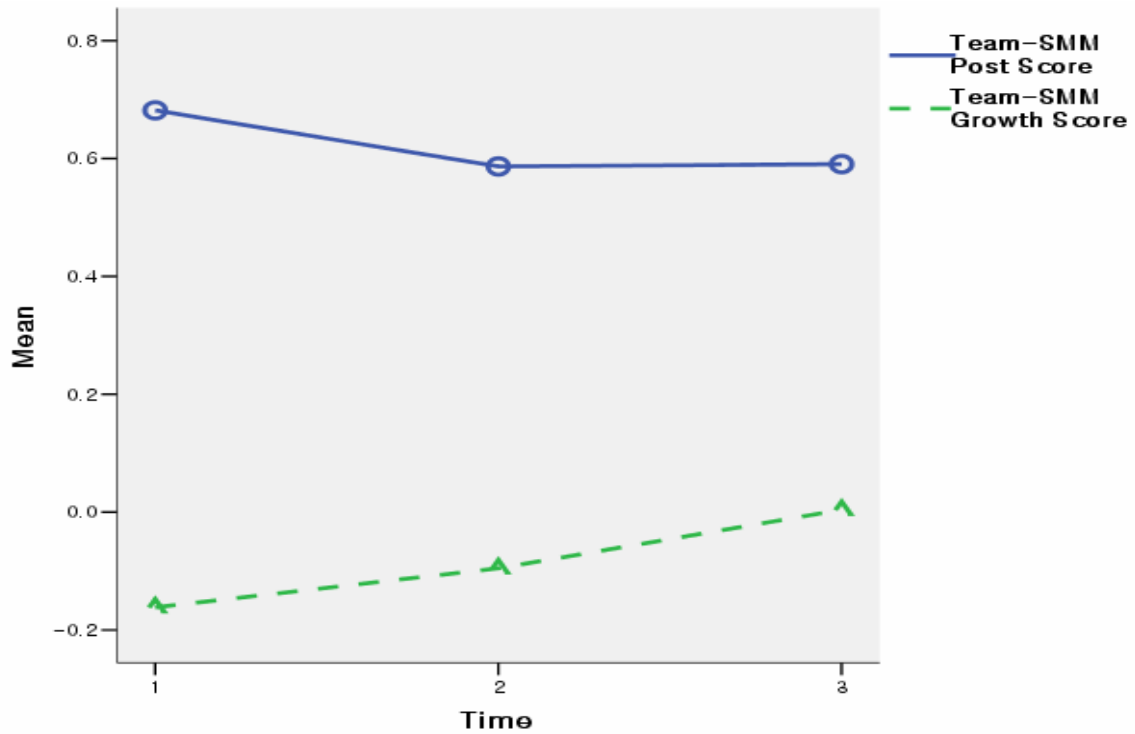


Figure 4.4. Changes of Post Score and Growth Score in Team-SMM Degree (Variance)

Even though both post score and growth score in Team-SMM Degree (Variance) did not show a statistically significant change over time, it is interesting that the post score in Team-SMM Degree (Variance) gradually decreased while the growth score in Team-SMM Degree (Variance) increased over time (see Figure 4.4.).

Operational Hypothesis 1.1.3.

1.1.3. The Average of the perception ratings about the Team-SMM Degree will increase over time.

Change of Post Score in Team-SMM Degree (Average)

The change of team members' perceptions on Team-SMM was analyzed with the average score of team members' ratings on the Team-SMM Degree questionnaire. Contrary to operational hypothesis 1.1.2, it was expected that the average scores would increase over time as in operational hypothesis 1.1.3. Operational hypothesis 1.1.3. was also examined with the post score and growth score in Team-SMM Degree. First, the change of post score in Team-SMM Degree was examined with one-way repeated measures ANOVA. Mauchly's test indicated that the assumption of sphericity had been violated ($\chi^2(2) = 17.50, p < .05$); therefore, the degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity ($\epsilon = .70$). The results showed that the Team-SMM Degree (Average) was significantly affected by time. $F(1.40, 44.71) = 9.26, p < 0.01$. A paired-samples t-test was conducted to examine the specific time period when the post scores in Team-SMM Degree (Average) changed. As the results, there were statistically significant increases in the scores from Time 1 ($M = 3.66, SD = 0.64$) to Time 2 ($M = 3.98, SD = 0.51$), $t(32) = -2.55, p < 0.05$, and from Time 2 ($M = 3.98, SD = 0.51$) to Time 3 ($M = 4.11, SD = 0.46$), $t(32) = -2.07, p < 0.05$. The following Table 4.6. shows the means and SDs of the post score in Team-SMM Degree (Average)

Table 4.6

Means and SDs of Post Score in Team-SMM Degree (Average)

Time Period	<i>k</i>	<i>M</i>	<i>SD</i>
Time 1	33	3.66	0.64
Time 2	33	3.98	0.51
Time 3	33	4.11	0.46

k= no. of teams

Change of Growth Score in Team-SMM Degree (Average)

In terms of the change of growth score in Team-SMM Degree (Average), one-way repeated measures ANOVA was also conducted. Mauchly's test indicated that the assumption of sphericity had been violated ($\chi^2(2) = 10.43, p < .05$); therefore, degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity ($\epsilon = 0.78$). The results showed that the Team-SMM Degree (Average) was significantly affected by time, $F(1.56, 49.78) = 18.07, p < 0.01$. A paired-samples t-test was conducted to see the difference per each phase. There was a statistically significant decrease of growth score in Team-SMM Degree (Average) from Time 1 ($M = 1.19, SD = 0.97$) to Time 2 ($M = 0.32, SD = 0.12$), $t(32) = 3.75, p < 0.01$ but there was no statistically significant change from Time 2 ($M = 1.19, SD = 0.97$) to Time 3 ($M = 0.13, SD = 0.06$), $t(32) = 1.21, p = 0.24$. The following Table 4.7. shows the Means and SDs of the growth score in Team-SMM Degree (Average) at each time.

Table 4.7.

Means and SDs for Growth Score about Team-SMM Degree (Average)

Time Period	<i>k</i>	<i>M</i>	<i>SD</i>
Time 1	33	1.19	0.97
Time 2	33	0.32	0.72
Time 3	33	0.13	0.36

k= no. of teams

The following figure 4.5. shows the visual representation of the change of post score and growth score in Team-SMM Degree (Average).

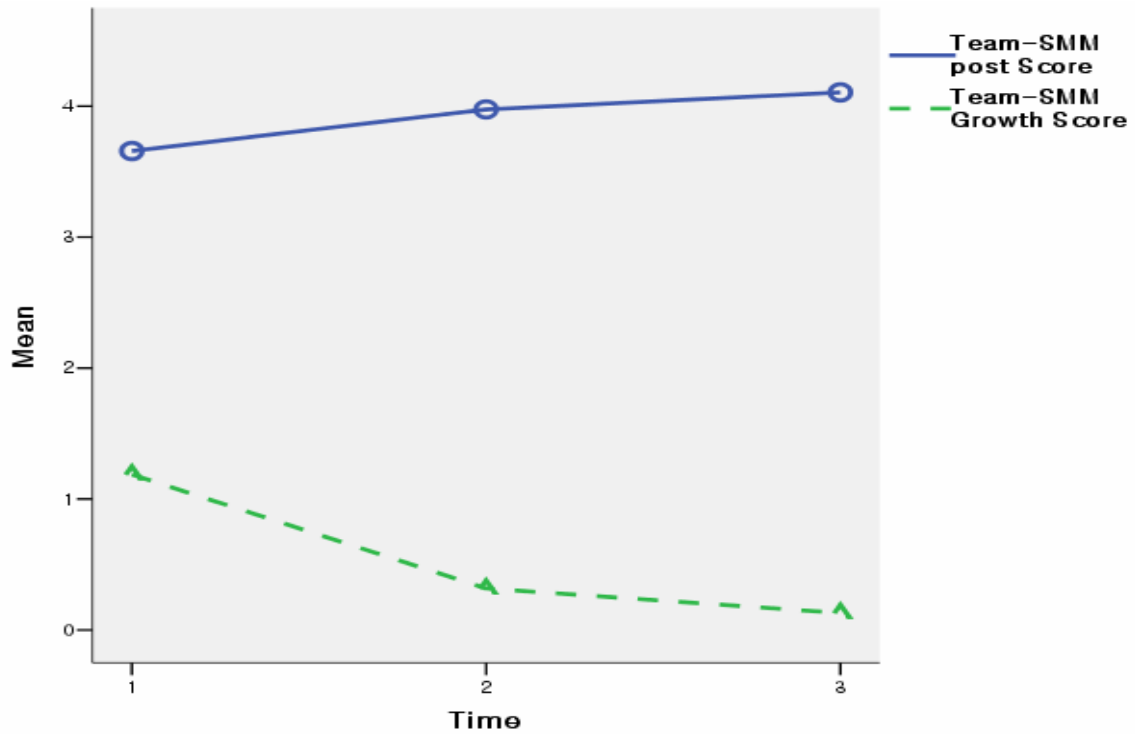


Figure 4.5. Changes of Post Score and Growth Score in Team-SMM Degree (Average)

As shown in Figure 4.5., the post scores of Team-SMM Degree (Average) significantly increased from Time 1 to Time 3. However, there was a significant decrease of the growth score of Team-SMM Degree (Average) from Time 1 to Time 2. The results imply that team members had moderately high shared mental models about teammate knowledge and team interaction from Time 1 to Time 3, but the growth score (post score minus pre score) of Team-SMM Degree slowly decreased over time. Namely, team members' perceptions on Team-SMM increased across the three time periods while their perceptions decreased within each time period.

Change of Task-SMM Structure and Task-SMM Degree over time

Like the investigation of the change in Team-SMM Structure and Team-SMM Degree over time, the change in Task-SMM Structure and Task-SMM Degree was also examined using one-way repeated measures ANOVA. Also, the post score and growth score of Task-SMM Structure and Task-SMM Degree collected at each of the three phases were used to see those changes. The following shows the results of the analyses corresponding to each operational hypothesis.

Operational hypothesis 2.1

2.1.1. Task-SMM Structure similarity scores produced by the Pathfinder program will increase over time.

Change of Post Score in Task-SMM Structure

One-way repeated measures ANOVA was performed to see the change of post score in Task-SMM Structure. The result shows that the Task-SMM Structure was significantly affected by time, $F(2, 64) = 9.676, p < 0.001$. In order to see the specific differences per each three phase, a paired-samples t-test was conducted. As the results indicate, there was a statistically significant decrease from Time 1 ($M = 46.45, SD = 15.13$) to Time 2 ($M = 32.85, SD = 14.37$), $t(32) = 4.27, p < 0.001$, but there was no significant change from Time 2 ($M = 32.85, SD = 14.37$) to Time 3 ($M = 35.91, SD = 15.35$), $t(32) = -1.11, p = 0.27$. The following Table 4.8. shows the means and SDs of post score in Task-SMM Structure.

Table 4.8.

Means and SDs of Post Score in Task-SMM Structure

Time period	<i>k</i>	<i>M</i>	<i>SD</i>
Time 1	33	46.45	15.13
Time 2	33	32.85	14.37
Time 3	33	35.91	15.35

k= no. of teams

Change of Growth Score in Task-SMM Structure

The change of growth score in Task-SMM Structure was also examined with one-way repeated measures ANOVA. The result shows that the growth score in Task-SMM Structure did not significantly change over time $F(2, 64) = 0.21, p = 0.81$. The following Table 4.9. shows the means and SDs of growth score of Task-SMM Structure.

Table 4.9.

Means and SDs of Growth Score in Task-SMM Structure

Time period	<i>k</i>	<i>M</i>	<i>SD</i>
Time 1	33	4.00	22.94
Time 2	33	1.27	18.53
Time 3	33	1.27	13.69

k= no. of teams

The following Figure 4.6. shows the visual representation of the change of both post score and growth score in Task-SMM Structure.

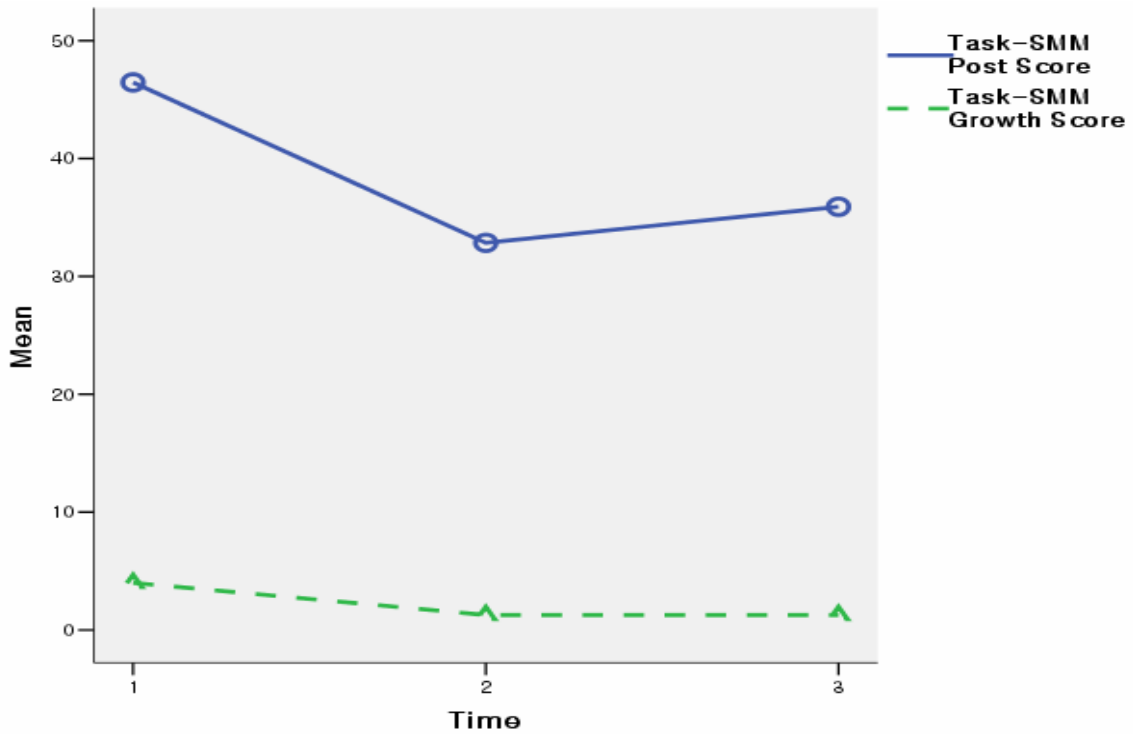


Figure 4.6. Changes of Post Score and Growth Score in Task-SMM Structure

As shown in Figure 4.6., at the time period from Time 1 to Time 2, both the post score and growth score in Task-SMM Structure decreased. However, the post score in Task-SMM Structure only showed a statistically significant decrease. This result implies that team members had a highly shared structure of task knowledge and team environment information at Time 1, but the sharedness gradually decreased from Time 1 to Time 2. On the other hand, from Time 2 to Time 3, the post score in Task-SMM Structure increased while its growth score kept the same level of similarity at the period. However, both post score and growth score did not show a statistically significant change at the time period.

2.1.2. The variance (standard deviation) of the perception ratings about the Task-SMM Degree will get closer (decrease) over time.

Change of Post Score in Task-SMM Degree (Variance)

In operational hypothesis 2.1.2., the variance of perception ratings on Task-SMM Degree was expected to decrease over time. The variance indicates the standard deviation between two team members' perception ratings on the Task-SMM Degree questionnaire. One-way repeated measures ANOVA was used to see if the post score in Task-SMM Degree (Variance) decreased. The result shows that the post score in Task-SMM Degree (Variance) significantly changed over time, $F(2, 64) = 12.93, p < 0.001$. A paired-samples t-test was conducted to see when the specific changes occurred. As expected, there was a significant decrease in Task-SMM Degree (Variance) from Time 2 ($M = 0.63, SD = 0.32$) to Time 3 ($M = 0.42, SD = 0.37$), $t(32) = 3.51, p < 0.01$. However, there was no significant decrease from Time 1 ($M = 0.71, SD = 0.45$) to Time 2 ($M = 0.63, SD = 0.32$), $t(32) = 1.36, p = 0.184$.

Table 4.10.

Means and SDs of Post Score in Task-SMM Degree (Variance)

Time period	<i>k</i>	<i>M</i>	<i>SD</i>
Time 1	33	0.71	0.45
Time 2	33	0.63	0.32
Time 3	33	0.42	0.37

k= no. of teams

Change of Growth Score in Task-SMM Degree (Variance)

The change of Task-SMM Degree (Variance) was also examined with the growth score obtained by the computation of post score minus pre score per each of the three time periods. One-way repeated measures ANOVA was conducted to examine the change of the growth score in Task-SMM Degree (Variance). The result shows that the growth score in Task-SMM Degree (Variance) did not significantly change over time $F(2,64) = 2.49, p = 0.09$. The following Table 4.11. shows the means and SDs of the growth score in Task-

SMM Degree(Variance).

Table 4.11.

Means and SDs of Growth Score in Task-SMM Degree (Variance)

Time period	k	M	SD
Time 1	33	-0.16	0.60
Time 2	33	-0.12	0.35
Time 3	33	-0.37	0.41

k= no. of teams

The following Figure 4.7. shows how the post score and growth score in Task-SMM Degree (Variance) changed over time.

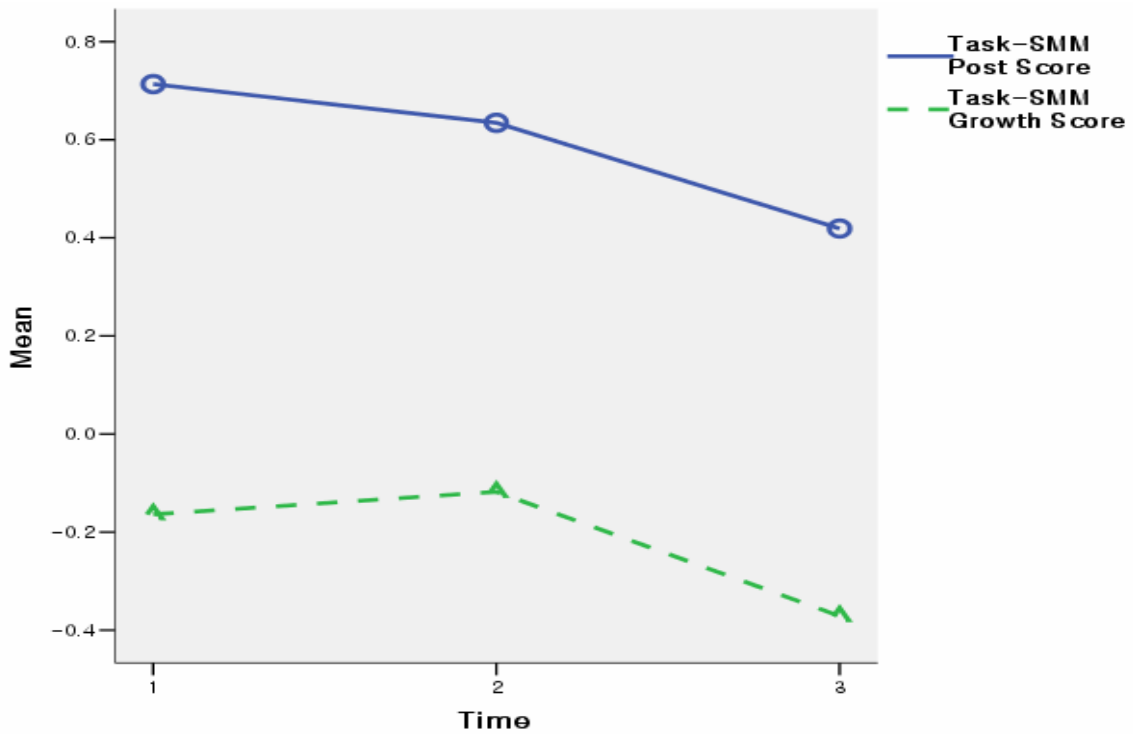


Figure 4.7. Changes of Post Score and Growth Score in Task-SMM Degree (Variance)

As shown in Figure 4.7., even though both post score and growth score were not statistically significantly changed from Time 1 to Time 2, the post score in Task-SMM

Degree (Variance) decreased while the growth score increased. From Time 2 to Time 3, the post score statistically significantly decreased while the growth score decreased without statistical power.

2.1.3. The average of the perception ratings about the Task-SMM Degree will increase over time.

Change of Post Score in Task-SMM Degree (Average)

The change of post score in Task-SMM Degree (Average) was examined by one-way repeated measures ANOVA. Mauchly’s test indicated that the assumption of sphericity had been violated, $\chi^2(2) = 37.28, p < 0.05$; therefore, degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity ($\epsilon = 0.59$). The results show that the Task-SMM Degree (Average) was significantly affected by time. $F(1.18, 37.66) = 32.82, p < 0.001$. A paired-samples t-test was conducted to see the difference per each time period. There were statistically significant increases from Time 1 ($M = 3.35, SD = 0.87$) to Time 2 ($M = 3.69, SD = 0.33$), $t(32) = -2.47, p < 0.05$ and from Time 2 ($M = 3.69, SD = 0.33$) to Time 3 ($M = 4.44, SD = 0.38$), $t(32) = -10.23, p < 0.001$. The following Table 4.12. shows the means and SDs for the post score in Task-SMM Degree (Average).

Table 4.12.

Means and SDs of Post Score in Task-SMM Degree (Average)

Time period	<i>k</i>	<i>M</i>	<i>SD</i>
Time 1	33	3.35	0.87
Time 2	33	3.69	0.33
Time 3	33	4.44	0.38

k= no. of teams

Change of Growth Score in Task-SMM Degree (Average)

Operation hypothesis 2.1.3 was also tested with the growth score in Task-SMM Degree (Average). One-way repeated measures ANOVA was employed to examine the change of the growth score in Task-SMM Degree (Average) over time. Mauchly's test indicated that the assumption of sphericity had been violated ($\chi^2(2) = 34.56, p < 0.001$); therefore, the degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity ($\epsilon = 0.60$). The result shows that the Task-SMM Degree (Average) was not significantly affected by time, $F(1.20, 38.28) = 2.41, p = 0.124$. The following Table 4.13. shows the means and SDs of the growth score in Task-SMM Degree (Average).

Table 4.13.

Means and SDs of Growth Score in Task-SMM Degree (Average)

Time period	<i>k</i>	<i>M</i>	<i>SD</i>
Time 1	33	0.62	1.35
Time 2	33	0.50	0.74
Time 3	33	1.16	1.16

k= no. of teams

The following Figure 4.8. shows a visual representation of the change of post score and growth score in Task-SMM Degree (Average).

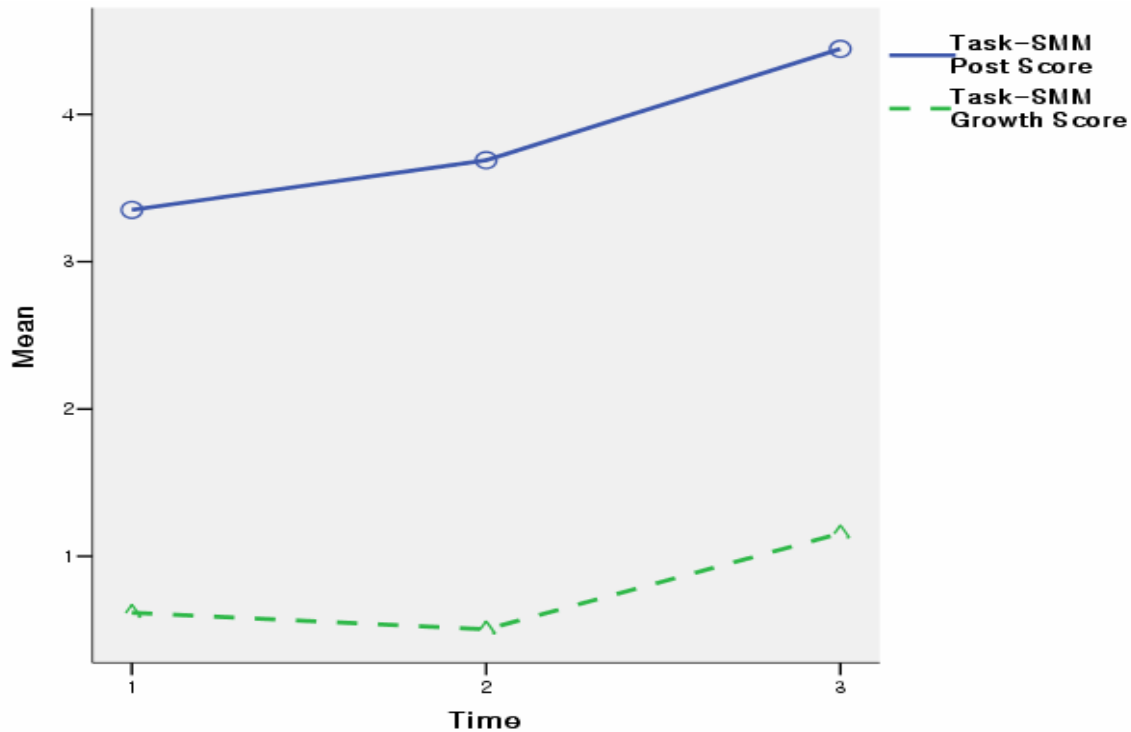


Figure 4.8. Changes of Post Score and Growth Score in Task-SMM Degree (Average)

Statistically significant increases appeared in the post score of Task-SMM Degree (Average) from Time 1 to Time 2 and from Time 2 to Time 3. Also, there was a decrease of the growth score of Task-SMM Degree (Average) from Time 1 to Time 2 and an increase of the growth score of Task-SMM Degree (Average) from Time 2 to Time 3 even though they were not statistically significant. The results imply that the team members' perceptions on Task-SMM that consisted of task knowledge and team environment statistically increased over time even though the growth score did not statistically increase over time.

Summary of the Changes in Team-SMM and Task-SMM

Overall, Team-SMM and Task-SMM changed over time; however their changes happened differently depending on measurement of the structure, degree (Variance) and degree (average) of Team-SMM or Task-SMM. Moreover, the changes of Team-SMM and Task-SMM varied depending on the specific time period of the team project. The following Table 4.14. shows the summary of the change of Team-SMM and Task-SMM in terms of

their structure and degree (Variance and Average).

Table 4.14.

Summary of the Changes in Team-SMM and Task-SMM

SMMs	Score	Time 1 - Time 2	Time 2 - Time 3		
Team-SMM	Structure	Post Score	+	ϕ	
		Growth Score	ϕ	ϕ	
	Degree (Variance)	Post Score	ϕ	ϕ	
		Growth Score	ϕ	ϕ	
	Degree (Average)	Post Score	+	+	
		Growth Score	-	ϕ	
	Task-SMM	Structure	Post Score	-	ϕ
			Growth Score	ϕ	ϕ
Degree (Variance)		Post Score	ϕ	-	
		Growth Score	ϕ	ϕ	
Degree (Average)		Post Score	+	+	
		Growth Score	ϕ	ϕ	

Notes: +: statistically significant increase, - : statistically significant decrease, ϕ : no statistically significant results

Comparing the results of the changes in Team-SMM Structure and Task-SMM Structure, the post score of Team-SMM structure significantly increased while the post score of Task-SMM Structure significantly decreased from Time 1 to Time 2. Namely, team members built a shared structure of Team-SMM which consists of teammate knowledge and team interaction rather than the structure of Task-SMM which has task knowledge and team environment at the beginning of their team project.

Comparing the change of participants' perceptions on Team-SMM Degree and Task-SMM Degree, there was no significant change in both post and growth scores in

Team-SMM Degree (Variance). However, there was a significant decrease of the post score of Task-SMM Degree (Variance) from Time 2 to Time 3 even though it did not significantly decrease from Time 1 to Time 2. On the other hand, the post scores of Team-SMM Degree (Average) and Task-SMM Degree (Average) increased from Time 1 to Time 3. The results fully support operational hypotheses 1.1.3 and 2.1.3. On the other hand, the growth score of Team-SMM Degree (Average) decreased from Time 1 to Time 2 implying that higher shared perception on Team-SMM occurred at Time 1 than at Time 2. The following Figure 4.9. depicts the graphical representation of the changes in Team-SMM and Task-SMM in terms of their structure, degree (Variance) and degree (Average).

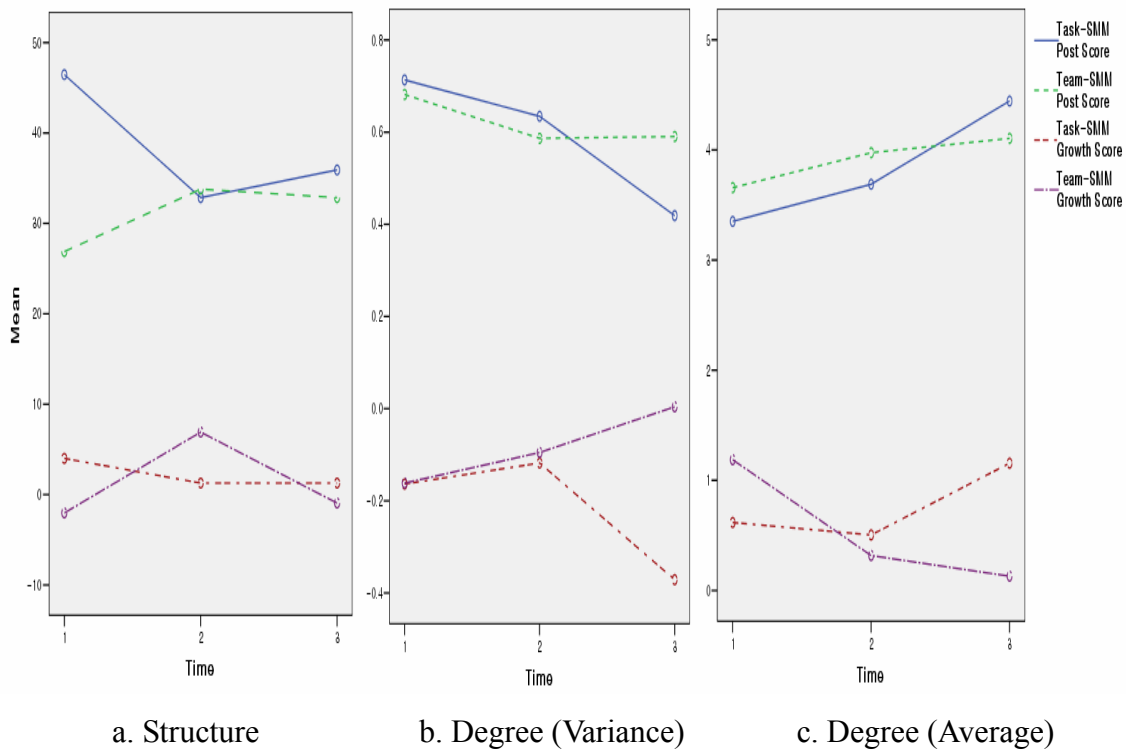


Figure 4.9. Graphical Representation of the Changes in Team-SMM and Task-SMM in terms of their Structure, Degree (Variance), and Degree (Average)

As shown in Figure 4.9, the first graph (a) shows the change of Task-SMM Structure and Team-SMM Structure. Task-SMM Structure and Team-SMM Structure show the opposite direction of change from Time 1 to Time 3. Namely, post score and growth score of Task-SMM Structure decreased from Time 1 to Time 2 and the scores increased

from Time 2 to Time 3. On the other hand, the post score and growth score of Team-SMM Structure increased from Time 1 to Time 2 and the scores decreased from Time 2 to Time 3.

In terms of Task-SMM Degree (Variance) and Team-SMM Degree (Variance) in the second graph (b), the post scores of both Task-SMM Degree (Variance) and Team-SMM Degree (Variance) decreased from Time 1 to Time 2. Even though the growth scores of Task-SMM Degree (Variance) and Team-SMM Degree (Variance) did not significantly change over time, the growth scores of Task-SMM Degree (Variance) and Team-SMM Degree (Variance) increased from Time 1 to Time 2. Interestingly, the growth score of Team-SMM Degree (Variance) continued to increase from Time 2 to Time 3; however, the score of Task-SMM Degree (Variance) decreased from Time 2 to Time 3.

Lastly, the results of changes in Task-SMM Degree (Average) and Team-SMM Degree (Average) were compared. The post scores of both Task-SMM Degree (Average) and Team-SMM Degree (Average) significantly increased over time. However, the growth score of Task-SMM Degree (Average) gradually increased from Time 2 to Time 3 even though the increase was not statistically significant. On the other hand, the growth score of Team-SMM Degree (Average) significantly decreased from Time 1 to Time 2 implying the growth score at Time 1 was higher than the growth score at Time 2. That is, team members built a highly-shared perception on Team-SMM at Time 1 and the sharedness gradually decreased from Time 1 to Time 2.

Is Team-SMM or Task-SMM the better predictor of performance?

As the second main research topic, this study investigated the relationship between shared mental models and performance. Specifically, this study examined whether Team-SMM or Task-SMM was the better predictor of team and/or individual performance over time.

Depending on the specific time period of the team project, the unique effect of Team-SMM and Task-SMM on team and individual performance was expected. In addition, team and individual performance were expected to increase as Team-SMM and Task-SMM scores increased. Due to the research questions that concern the change of predictors and their effects on the change of dependent variables, random-effects regression and fixed-effects regression were selectively used to explain not only change over time but also differences among units. To verify the use of random-effects regression, the Breusch-Pagan Lagrange Multiplier Test² and the Hausman Specification Test³ were performed in every analysis in order to determine whether random or fixed-effects models were more appropriate. Moreover, to capture the influence of shared mental models on performance in specific time periods, time dummy variables were used. Instead of using Time 1 as the baseline, Time 2 was used to examine the specific time effect, (i.e., the change from Time 1 to Time 2 and the change from Time 2 to Time 3). Therefore, Time 2 was coded 0, 0 as a reference time and Time 1 and Time 3 were respectively coded -1, 0 and 0,+1 to represent the time periods before Time 2 and after Time 2. The following Table 4.15 shows an example on how the data set was restructured with the time dummy variables.

² Breusch-Pagan (1979) tests pooled regression against the random-effects model. If the null hypothesis which suggests the variances of groups are zero is rejected, the random-effects model is appropriate. (Baltagi, 2001).

³ The Hausman Specification Test (1978) test is used to decide which model is more valid. The null hypothesis is that the coefficients estimated by the efficient random-effects estimator are the same as the ones estimated by the consistent fixed-effects estimator. It is safe to use random-effects if they are insignificant. Otherwise, fixed effect regression is more appropriate than random-effects regression.

Table 4.15.

Example of the Restructured Data Set with Time Dummy Variables

ID	Time	Task Post ^a	Team Post ^b	Task Growth ^c	Team Growth ^d	IP ^e	T1 ^f	T2 ^g
1	1	4.81	4.84	1.74	1.71	50.00	-1	0
1	2	3.81	4.47	-.82	-.37	62.50	0	0
1	3	4.44	4.41	.57	-.06	90.00	0	1
2	1	4.81	4.84	1.74	1.71	62.50	-1	0
2	2	3.81	4.47	-.82	-.37	50.00	0	0
2	3	4.44	4.41	.57	-.06	75.00	0	1
3	1	4.17	3.54	2.17	1.78	57.50	-1	0
3	2	4.38	4.42	.42	.88	52.50	0	0
3	3	4.42	4.38	.05	-.04	32.50	0	1
4	1	4.17	3.54	2.17	1.78	57.50	-1	0
4	2	4.38	4.42	.42	.88	50.00	0	0
4	3	4.42	4.38	.05	-.04	47.50	0	1

Note: a. Post Score of Task-SMM
 b. Post Score of Team-SMM
 c. Growth score of Task-SMM
 d. Growth score of Team-SMM
 e. Individual performance score
 f. Time dummy variable indicating the time period from Time 1 to Time 2
 g. Time dummy variable indicating the time period from Time 2 to Time 3

In this study, the post scores and growth scores of Team-SMM and Task-SMM were respectively considered to examine each hypothesis on the influence of Team-SMM and Task-SMM on team and individual performance. Here, the growth score indicates a gain score between pretest and post test of shared mental models estimation. The following shows two models dealt with in this study.

1. Model with Post Scores of SMMs and Performance:

$$Y_{it} = \beta_0 + \beta_1 \text{Task-SMM}_{it} + \beta_2 \text{Team-SMM}_{it} + \beta_3 T1_i + \beta_4 T2_i + \beta_5 T1 * \text{Task-SMM}_{it} + \beta_6 T1 * \text{Team-SMM}_{it} + \beta_7 T2 * \text{Task-SMM}_{it} + \beta_8 T2 * \text{Team-SMM}_{it} + e_{it}$$

- Y_{it} : Team performance score or Individual performance score for the i th team or individual at Time t .
- β_0 : The average value of the dependent variables when Time= 0
- β_1 : The average change in dependent variables for each one unit of the post score of Task-SMM increase at Time t
- β_2 : The average change in dependent variables for each one unit of the post score of Team-SMM increase at Time t
- β_3 : The average change in dependent variables from Time 1 to Time 2
- β_4 : The average change in dependent variables from Time 2 to Time 3
- β_5 : The interaction effect of dummy variable indicating the period from Time 1 to Time 2 and the post score of Task-SMM on the average change in dependent variables
- β_6 : The interaction effect of dummy variable indicating the period from Time 1 to Time 2 and the post score of Team-SMM on the average change in dependent variables
- β_7 : The interaction effect of dummy variable indicating the period from Time 2 to Time 3 and the post score of Task-SMM on the average change in dependent variables
- β_8 : The interaction effect of dummy variable indicating the period from Time 2 to Time 3 and the post score of Team-SMM on the average change in dependent variables
- e_{it} : The random errors.

2. Model with Growth Scores of SMMs and Performance:

$$Y_{it} = \beta_0 + \beta_1 \Delta \text{Task-SMM}_{it} + \beta_2 \Delta \text{Team-SMM}_{it} + \beta_3 T1_i + \beta_4 T2_i + \beta_5 T1 * \Delta \text{Task-SMM}_{it} + \beta_6 T1 * \Delta \text{Team-SMM}_{it} + \beta_7 T2 * \Delta \text{Task-SMM}_{it} + \beta_8 T2 * \Delta \text{Team-SMM}_{it} + e_{it}$$

- Y_{it} : Team performance score or Individual performance score for the i th team or individual at Time t .
- β_0 : The average value of the dependent variables when Time= 0
- β_1 : The average change in dependent variables for each one unit of the growth score of Task-SMM increase at Time t
- β_2 : The average change in dependent variables for each one unit of the growth score of Team-SMM increase at Time t

- β_3 : The average change in dependent variables from Time 1 to Time 2
- β_4 : The average change in dependent variables from Time 2 to Time 3
- β_5 : The interaction effect of dummy variable indicating the period from Time 1 to Time 2 and the growth score of Task-SMM on the average change in dependent variables
- β_6 : The interaction effect of dummy variable indicating the period from Time 1 to Time 2 and the growth score of Team-SMM on the average change in dependent variables
- β_7 : The interaction effect of dummy variable indicating the period from Time 2 to Time 3 and the growth score of Task-SMM on the average change in dependent variables
- β_8 : The interaction effect of dummy variable indicating the period from Time 2 to Time 3 and the growth score of Team-SMM on the average change in dependent variables
- e_{it} : The random errors.

Team Performance: Team-SMM or Task-SMM

Team performance was expected to increase as Team-SMM or Task-SMM increased over time. Random-effects GLS regression was used to analyze how Team-SMM or Task-SMM affects team performance over time. The post score and growth score of Team-SMM and Task-SMM were respectively used for the analyses. The results of analyses are presented corresponding to operational hypotheses 3.1.1, 3.2.1, and 3.2.2.

Operational hypothesis 3.1.1

3.1.1. As the similarity score on **Team-SMM Structure** or **Task-SMM Structure** increase, the **team performance** score will show a statistically significant increase.

Post Score of SMMs Structure and Team Performance

Hypothesis 3.1.1 suggests that the team performance score will show a statistically significant increase as the similarity score on Team-SMM Structure or Task-SMM Structure increases. This hypothesis was tested to examine the incremental predictability of the similarity score on Team-SMM Structure or Task-SMM Structure for team performance.

The overall model indicates a good fit with the data explaining about 58 % of the variation in team performance. As the results of the Breusch-Pagan Lagrange Multiplier test indicate, the calculated chi-square test statistic of 25.41 rejects the null hypothesis of

zero variance at the 1% significance level. In terms of the Hausman specification test, the calculated test statistics do not reject the null hypothesis at the 1 % significance level. This justifies the use of the random-effects estimations rather than the fixed-effects estimations.

As the results of the analysis indicate, each coefficient of the post scores of Task-SMM Structure and Team-SMM Structure does not significantly affect the increase of the average score in team performance. Also, they do not have any statistically significant impact on team performance in the specific time periods (i.e., from Time 1 to Time 2 and from Time 2 to Time 3). The following Table 4.16 shows the summary of the results.

Table 4.16.

Results from Random-Effects GLS Regression of the Post Scores of Task-SMM Structure and Team-SMM Structure on Team Performance

Variable	Coefficient Estimate	Z-statistics	P>abs. Z
Constant	18.486	16.03	0.000
Task-SMM Post Score	-0.008	-0.29	0.769
Team-SMM Post Score	-0.008	-0.30	0.766
T1	5.173	2.99	0.003
T2	3.067	2.10	0.036
T1 * Task-SMM Post Score	-0.036	-0.97	0.332
T1 * Team-SMM Post Score	0.007	0.14	0.890
T2 * Task-SMM Post Score	0.005	0.14	0.888
T2 * Team-SMM Post Score	0.011	0.30	0.767
R-square:	within = 0.8155 between = 0.0034 overall = 0.5763		
Number of Observation	99		
Wald Test chi2(8)	266.09		
Prob>chi-square	0.0000		
Breusch-Pagan Lagrange Multiplier Test:	Null Hypotheses: Var(u) =0 Calculated Chi-square(1) = 25.41 Prob > chi-square = 0.0000		
Hausman Specification test:	Null Hypothesis: No systematic difference in coefficients Calculated Chi-square(8) = 2.59 Prob > chi-square = 0.9574		

Notes: Model: Team Performance = $\beta_0 + \beta_1$ Task-SMM+ β_2 Team-SMM+ β_3 T1 + β_4 T2+ β_5 T1Task-SMM + β_6 T1Team-SMM + β_7 T2Task-SMM+ β_8 T2Team-SMM, *** $p \leq .001$, ** $p \leq .01$, * $p \leq .05$

Growth Score of SMMs Structure and Team Performance

To examine operational hypothesis 3.1.1, it was investigated how the growth scores of Task-SMM Structure and Team-SMM Structure affect the team performance score over time. The following Table 4.16 shows the results from panel data estimation using the random-effects GLS regression. The Breusch-Pagan Lagrange Multiplier Test and the Hausman Specification test suggested the random-effects model is appropriate. The overall R² indicates a good fit with the data explaining about 58 % of the variation in team performance. However, the results of the analysis revealed no significant influence of the growth scores of Team-SMM Structure and Task-SMM Structure on team performance. The results are summarized in Table 4.17.

Table 4.17.

Results from Random-Effects GLS Regression of the Growth Scores of Task-SMM Structure and Team-SMM Structure on Team Performance

Variable	Coefficient Estimate	Z-statistics	P>abs. Z
Constant	17.839	35.52	0.000
Task-SMM Growth Score	-0.003	-0.13	0.897
Team-SMM Growth Score	0.013	0.45	0.652
T1	3.533	6.99	0.000
T2	3.634	7.44	0.000
T1 * Task-SMM Growth Score	0.003	0.13	0.899
T1 * Team-SMM Growth Score	-0.029	-0.60	0.546
T2 * Task-SMM Growth Score	0.043	1.25	0.211
T2 * Team-SMM Growth Score	-0.002	-0.06	0.951
R-square:	within = 0.8216 between = 0.0077 overall = 0.5818		
Number of Observation	99		
Wald Test chi2(8)	272.41		
Prob>chi-square	0.0000		
Breusch-Pagan Lagrange Multiplier Test:	Null Hypotheses: Var (u) =0 Calculated Chi-square(1) = 25.77 Prob > chi-square = 0.0000		
Hausman Specification test:	Null Hypothesis: No systematic difference in coefficients Calculated Chi-square(8) = 4.18 Prob > chi-square = 0.8407		

Notes: Model: Team Performance = $\beta_0 + \beta_1 \Delta$ Task-SMM + $\beta_2 \Delta$ Team-SMM + β_3 T1 + β_4 T2 + β_5 T1 Δ Task-SMM + β_6 T1 Δ Team-SMM + β_7 T2 Δ Task-SMM + β_8 T2 Δ Team-SMM, *** $p \leq .001$,

****** $p \leq .01$, ***** $p \leq .05$

Based on the results of the influences of post scores and growth scores of Task-SMM Structure and Team-SMM Structure on team performance described above, operational hypothesis 3.1.1 was not supported by the findings.

Operational hypothesis 3.2.1

3.2.1. As the variance of the perception ratings about **Team-SMM Degree** or **Task-SMM Degree** decrease, the team performance score will show a statistically significant increase.

Post Score of SMMs Degree (Variance) and Team Performance

In operational hypothesis 3.2.1, the negative relationships between SMM Degree (Variance) and team performance were expected. Namely, it was expected that team performance would increase as the variance of Task-SMM Degree and Team-SMM Degree decreased over time. The hypothesis was examined with the post scores of Task-SMM Degree (Variance) and Team-SMM Degree (Variance). The Breusch-Pagan Lagrange Multiplier Test and the Hausman Specification Test were conducted to see the appropriateness of using random-effects GLS regression. As the results indicate, the choice of using the random-effects GLS regression was justified. The overall R^2 indicates a good fit with the data, explaining about 60 % of the variation in team performance. As expected in the hypothesis, from Time 2 to Time 3, the one point increase of Task-SMM Degree (Variance) led to the decrease of the average score in team performance of around 3.767 points at the 5% significant level. Namely, the variance of Task-SMM Degree has a negative relationship with performance from Time 2 to Time 3. The following Table 4.18. shows the results.

Table 4.18.

Results from Random-Effects GLS Regression of the Post Scores of Task-SMM Degree (Variance) and Team-SMM Degree (Variance) on Team Performance

Variable	Coefficient Estimate	Z-statistics	P>abs. Z
Constant	17.620	19.21	0.000
Task-SMM Post Score	-0.043	0.03	0.975
Team-SMM Post Score	0.565	0.55	0.580
T1	3.601	3.68	0.000
T2	4.426	4.72	0.000
T1 * Task-SMM Post Score	0.149	0.09	0.930
T1 * Team-SMM Post Score	0.104	0.07	0.943
T2 * Task-SMM Post Score	-3.767 *	-2.01	0.044
T2 * Team-SMM Post Score	1.237	0.89	0.376
R-square:	within = 0.8301 between = 0.0678 overall = 0.6028		
Number of Observation	99		
Wald Test chi2(11)	283.94		
Prob>chi-square	0.0000		
Breusch-Pagan Lagrange Multiplier Test:	Null Hypotheses: Var(u) = 0 Calculated Chi-square(1) = 26.15 Prob > chi-square = 0.0000		
Hausman Specification test:	Null Hypothesis: No systematic difference in coefficients Calculated Chi-square(8) = 12.19 Prob > chi-square = 0.1428		

Notes: Model: Team Performance = $\beta_0 + \beta_1$ Task-SMM + β_2 Team-SMM + β_3 T1 + β_4 T2 + β_5 T1Task-SMM + β_6 T1Team-SMM + β_7 T2Task-SMM + β_8 T2Team-SMM, *** $p \leq .001$, ** $p \leq .01$, * $p \leq .05$

Growth Score of SMMs Degree (Variance) and Team Performance

Operational hypothesis 3.2.1 was also tested with the growth scores of Team-SMM Degree (Variance) and Task-SMM Degree (Variance). It was expected that team performance would decrease as the growth scores of Team-SMM Degree (Variance) and Task-SMM Degree (Variance) increased over time. First, the Hausman Specification test was performed to determine the appropriate estimation. The Hausman Specification test rejected the null hypothesis (H0: the differences in the estimated coefficients between the fixed-effects model and the random-effects model are not systematic); thus, the fixed-effects model was carried out to examine how much the growth scores of Task-SMM

Degree(Variance) and Team-SMM Degree (Variance) explain the increase of team performance.

Overall R-square value was 0.5675 (i.e., the variables accounted for about 57 % of the total variance in team performance). The growth scores of Task-SMM Degree (Variance) and Team-SMM Degree (Variance) were not statistically significant in the regression. Therefore, they did not have any statistical impacts on team performance scores over time. The results are summarized in Table 4.19.

Table 4.19.

Results from Fixed-Effects Regression of the Growth Scores of Task-SMM Degree (Variance) and Team-SMM Degree (Variance) on Team Performance

Variable	Coefficient Estimate	t	P>abs. t
Constant	17.9038	49.74	0.000
Task-SMM Growth Score	0.049	0.04	0.967
Team-SMM Growth Score	-0.276	-0.26	0.797
T1	3.682	7.37	0.000
T2	3.408	5.49	0.000
T1 * Task-SMM Growth Score	-0.207	-0.15	0.881
T1 * Team-SMM Growth Score	-0.172	-0.13	0.894
T2 * Task-SMM Growth Score	-0.581	-0.34	0.736
T2 * Team-SMM Growth Score	1.831	1.00	0.323
R-square:	within = 0.8173 between = 0.0133 overall = 0.5675		
Number of Observation	99		
F(8,58)	32.43		
Prob>F	0.0000		
Breusch-Pagan Lagrange Multiplier Test:	Null Hypotheses: Var(u) = 0 Calculated Chi-square(1) = 15.94 Prob > chi-square = 0.0001		
Hausman Specification test:	Null Hypothesis: No systematic difference in coefficients Calculated Chi-square(8) = 20.54 Prob > chi-square = 0.0085		

Notes: Model: Team Performance = $\beta_0 + \beta_1 \Delta$ Task-SMM + $\beta_2 \Delta$ Team-SMM + β_3 T1 + β_4 T2 + β_5 T1 Δ Task-SMM + β_6 T1 Δ Team-SMM + β_7 T2 Δ Task-SMM + β_8 T2 Δ Team-SMM
 *** $p \leq .001$, ** $p \leq .01$, * $p \leq .05$

Based on the results of the influences of post scores and growth scores of Task-SMM Degree (Variance) and Team-SMM Degree (Variance) on team performance, it can be concluded that the post score of Task-SMM Degree (Variance) only has impact on team performance from Time 2 to Time 3. Supporting operational hypothesis 3.2.1, team performance decreased as the post score of Task-SMM Degree (Variance) increased.

Operational hypothesis 3.2.2.

3.2.2. As the **average** score of the **Team-SMM Degree** or **Task-SMM Degree** increase, the **team performance** score will show a statistically significant increase

Post Score of SMMs Degree (Average) and Team Performance

In hypothesis 3.2.2., it was hypothesized that team performance scores will increase as the average scores of Team-SMM Degree or Task-SMM Degree increase. At first, the hypothesis was tested with the post scores of Task-SMM Degree (Average) and Team-SMM Degree (Average). As the results of Hausman Specification test indicate, the null hypothesis was rejected so that the fixed-effects model was carried out to examine how much the post scores of Task-SMM Degree (Average) and Team-SMM Degree (Average) influenced team performance over time.

As shown in Table 4.20., the post score of Task-SMM Degree (Average) had a significant influence on team performance. As the post score of Task-SMM Degree (Average) increased by one point, team performance increased by approximately 4.266 points. In the specific time period from Time 1 to Time 2, Task-SMM Degree (Average) had a positive relationship with team performance while Team-SMM Degree (Average) had a negative relationship with team performance. Namely, a one-point increase in the post score of Task-SMM Degree (Average) led to a 5.613 point increase of the average in team performance. However, around 2.954 points of the average in team performance decreased as the Team-SMM Degree (Average) increased by one point.

On the other hand, there were no statistically significant impacts of Task-SMM Degree (Average) and Team-SMM Degree (Average) on team performance from Time 2 to

Time 3. The following Table 4.20. shows the summary of the results.

Table 4.20.

Results from Fixed-Effects Regression of the Post Scores of Task-SMM Degree (Average) and Team-SMM Degree (Average) on Team Performance

Variable	Coefficient Estimate	t	P>abs. t
Constant	7.159	1.59	0.118
Task-SMM Post Score	4.266 ***	3.73	0.000
Team-SMM Post Score	-1.250	-1.63	0.108
T1	-5.318	-1.24	0.219
T2	2.641	0.45	0.653
T1 * Task-SMM Post Score	5.613 ***	4.58	0.000
T1 * Team-SMM Post Score	-2.954 **	-2.96	0.004
T2 * Task-SMM Post Score	-1.335	-0.99	0.328
T2 * Team-SMM Post Score	0.931	1.04	0.303
R-square:	Within = 0.8694 between = 0.7264 Overall = 0.7741		
Number of Observation	99		
F(8,58)	48.26		
Prob>F	0.0000		
Breusch-Pagan Lagrange Multiplier Test:	Null Hypotheses: Var(u) = 0 Calculated Chi-square(1) = 2.51 Prob > chi-square = 0.1130		
Hausman Specification test:	Null Hypothesis: No systematic difference in coefficients Calculated Chi-square(8) = 16.08 Prob > chi-square = 0.0412		

Notes: Model: Team Performance = $\beta_0 + \beta_1$ Task-SMM+ β_2 Team-SMM+ β_3 T1 + β_4 T2+ β_5 T1Task-SMM + β_6 T1Team-SMM + β_7 T2Task-SMM+ β_8 T2Team-SMM, *** $p \leq .001$, ** $p \leq .01$, * $p \leq .05$

Growth Score of SMMs Degree (Average) and Team Performance

Operational hypothesis 3.2.2 was also examined with the growth scores of Task-SMM Degree (Average) and Team-SMM Degree (Average). The Breusch-Pagan Lagrange Multiplier test and the Hausman Specification test were conducted to see if random-effects regression was appropriate. However, the null hypothesis in the Hausman specification test was rejected at the 1% significant level. Therefore, the fixed-effects model is more efficient

to estimate the empirical model.

As shown in Table 4.21., there were no overall impacts of the growth scores of Task-SMM Degree (Average) and Team-SMM Degree (Average) on team performance. However there was a significantly negative influence of Team-SMM Degree (Average) on team performance from Time 1 to Time 2. The effect of the growth score of Team-SMM Degree (Average) on team performance from Time 1 to Time 2 corresponded to a slope of -1.667. This finding implies that the team performance score is predicted to decrease 1.667 points of its average for every one point that the growth score of Team-SMM Degree (Average) increases. The following Table 4.21 shows the summary of the results.

Table 4.21.

Results from Fixed-Effects Regression of the Growth Scores of Task-SMM Degree (Average) and Team-SMM Degree (Average) on Team Performance

Variable	Coefficient Estimate	t	P>abs. t
Constant	17.594	38.76	0.000
Task-SMM Growth Score	1.009	1.47	0.148
Team-SMM Growth Score	-0.565	-0.99	0.326
T1	4.248	5.75	0.000
T2	2.916	4.59	0.000
T1 * Task-SMM Growth Score	1.750	1.87	0.067
T1 * Team-SMM Growth Score	-1.667*	-2.11	0.040
T2 * Task-SMM Growth Score	-0.124	-0.22	0.829
T2 * Team-SMM Growth Score	0.426	0.32	0.747
R-square:	within = 0.8375 between = 0.2909 overall = 0.6744		
Number of Observation	99		
F(8,58)	37.38		
Prob>F	0.0000		
Breusch-Pagan Lagrange Multiplier Test:	Null Hypotheses: Var(u) = 0 Calculated Chi-square(1) = 10.89 Prob > chi-square = 0.0010		
Hausman Specification test:	Null Hypothesis: No systematic difference in coefficients Calculated Chi-square(8) = 90.73 Prob > chi-square = 0.0000		

Notes: Model: Team Performance = $\beta_0 + \beta_1 \Delta$ Task-SMM+ $\beta_2 \Delta$ Team-SMM+ β_3 T1 + β_4 T2+ β_5 T1 Δ Task-SMM+ β_6 T1 Δ Team-SMM + β_7 T2 Δ Task-SMM+ β_8 T2 Δ Team-SMM, *** $p \leq .001$, ** $p \leq .01$, * $p \leq .05$

Based on the results of the influence of Task-SMM Degree (Average) and Team-SMM Degree (Average) on team performance, it can be concluded that operational hypothesis 3.2.2 was partially supported.

Predicting Individual Performance by Team-SMM and Task-SMM

This section shows the results of analyses of how much individual performance can be explained by Team-SMM Structure, Task-SMM Structure, Team-SMM Degree and Task-SMM Degree over time. It provides an indication about whether Team-SMM or Task-SMM is most likely to be the best predictor of individual performance over time. Random-effects GLS regression was generally used to test the operational hypotheses. However, fixed-effects regression was used in some analyses based on the results of the Breusch-Pagan Lagrange Multiplier test and the Hausman Specification test.

Operational hypothesis 4.1.1

4.1.1. As the similarity scores on **Team-SMM Structure** or **Task-SMM Structure** increase, the **individual performance** score will show a statistically significant increase.

Post score of SMMs Structure and Individual Performance

Operational hypothesis 4.1.1 was examined with the post scores of Task-SMM Structure and Team-SMM Structure. Since the null hypothesis of Hausman Specification test was not rejected, the random-effects model was used to examine how the increases of the post scores of Task-SMM Structure and Team-SMM Structure affect the improvement of individual performance.

Overall, the post scores of Task-SMM Structure and Team-SMM Structure did not have any statistically significant impact on individual performance. However, the post score of Team-SMM structure from Time 2 to Time 3 had a statistically significant positive impact on individual performance at the 5% significance level. Specifically, an increase of one point in the post score of Team-SMM Structure led to the increase of the average score in individual performance by 0.483 points holding all other independent variables constant.

The following table 4.22. shows the results of the analysis.

Table 4. 22.

Results from Random-Effects GLS Regression of the Post Scores of Task-SMM Structure and Team-SMM Structure on Individual Performance

Variable	Coefficient Estimate	Z-statistics	P>abs. Z
Constant	57.567	10.31	0.000
Task-SMM Post Score	-0.002	-0.01	0.991
Team-SMM Post Score	-0.177	-1.25	0.210
T1	-0.249	-0.03	0.978
T2	-15.339	-1.94	0.053
T1 * Task-SMM Post Score	0.084	0.43	0.669
T1 * Team-SMM Post Score	0.067	0.25	0.804
T2 * Task-SMM Post Score	0.148	0.77	0.440
T2 * Team-SMM Post Score	0.483 **	2.58	0.010
R-square:	within = 0.1950 between = 0.0013 overall = 0.1054		
Number of Observation	201		
Wald Test chi2(8)	29.38		
Prob>chi-square	0.0003		
Breusch-Pagan Lagrange Multiplier Test:	Null Hypotheses: Var(u) = 0 Calculated Chi-square(1) = 9.36 Prob > chi-square = 0.0022		
Hausman Specification test:	Null Hypothesis: No systematic difference in coefficients Calculated Chi-square(8) = 11.94 Prob > chi-square = 0.1539		

Notes: Model: Individual Performance = $\beta_0 + \beta_1$ Task-SMM+ β_2 Team-SMM+ β_3 T1 + β_4 T2+ β_5 T1Task-SMM + β_6 T1Team-SMM + β_7 T2Task-SMM+ β_8 T2Team-SMM, *** $p \leq .001$, ** $p \leq .01$, * $p \leq .05$

Growth Score of SMMs Structure and Individual Performance

Operational hypothesis 4.1.1 was also examined with the growth scores of Team-SMM Structure and Task-SMM Structure. The Breusch-Pagan Lagrange Multiplier test and the Hausman Specification test showed that the random-effects GLS regression model is more appropriate than the fixed-effects model.

Overall, the growth score of Team-SMM Structure affects the decrease of

individual performance. A one-point increase in the growth score of Team-SMM Structure led to the decrease in the average score of individual performance by 0.292 points. Also, there was a statistically significant increase of 0.513 points in the average score of individual performance as the growth score of Team-SMM Structure increased by one point from Time 2 to Time 3. The following Table 4.23 shows the results of the analysis.

Table 4.23.

Results from Random-Effects GLS Regression of the Growth Scores of Task-SMM Structure and Team-SMM Structure on Individual Performance

Variable	Coefficient Estimate	Z-statistics	P>abs. Z
Constant	53.614	24.45	0.000
Task-SMM Growth Score	-0.035	-0.33	0.740
Team-SMM Growth Score	-0.292*	-2.00	0.045
T1	6.716	2.40	0.016
T2	4.179	1.53	0.125
T1 * Task-SMM Growth Score	0.022	0.16	0.874
T1 * Team-SMM Growth Score	0.033	0.13	0.894
T2 * Task-SMM Growth Score	0.009	0.05	0.959
T2 * Team-SMM Growth Score	0.513**	2.74	0.006
R-square:	within = 0.1494 between = 0.1145 overall = 0.1295		
Number of Observation	201		
Wald Test chi2(8)	29.73		
Prob>chi-square	0.0002		
Breusch-Pagan Lagrange Multiplier Test:	Null Hypotheses: Var(u) = 0 Calculated Chi-square (1) = 4.94 Prob > chi-square = 0.0263		
Hausman Specification test:	Null Hypothesis: No systematic difference in coefficients Calculated Chi-square(8) = 5.45 Prob > chi-square = 0.7084		

Notes: Model: Individual Performance = $\beta_0 + \beta_1 \Delta$ Task-SMM + $\beta_2 \Delta$ Team-SMM + β_3 T1 + β_4 T2 + β_5 T1 Δ Task-SMM + β_6 T1 Δ Team-SMM + β_7 T2 Δ Task-SMM + β_8 T2 Δ Team-SMM, *** $p \leq .001$, ** $p \leq .01$, * $p \leq .05$

In sum, operational hypothesis 4.1.1. was partially supported based on the results of the influences of post scores or growth scores in Task-SMM Structure and Team-SMM Structure on individual performance.

Operational hypothesis 4.2.1

4.2.1. The variance of the perceptions ratings about the **Team-SMM Degree** or **Task-SMM Degree** increase, the **individual performance** score will show a statistically significant decrease.

Post score of SMMs Degree (Variance) and Individual Performance

In operational hypothesis 4.2.1, it was expected that individual performance would decrease as Team-SMM Degree (Variance) and Task-SMM Degree (Variance) increased. Operational hypothesis 4.2.1 was examined with the post scores of Task-SMM Degree (Variance) and Team-SMM Degree (Variance). Since the Hausman Specification test was not rejected, the random-effects GLS regression model was used.

Overall, it was revealed that the average of individual performance decreased as the post score of Task-SMM (Variance) increased over time. Namely, 14.082 points of the average in individual performance decreased as the post score of Task-SMM (Variance) increased by one point. However, at the specific time period from Time 2 to Time 3, the average score of individual performance increased by 24.059 points as the post score of Task-SMM Degree (Variance) increased by one point. The following Table 4.24. shows the summary of the results.

Table 4.24.

Results from Random-Effects GLS Regression of the Post Scores of Task-SMM Degree (Variance) and Team-SMM Degree (Variance) on Individual Performance

Variable	Coefficient Estimate	Z-statistics	P>abs. Z
Constant	61.283	14.32	0.000
Task-SMM Post Score	-14.082*	-2.03	0.043
Team-SMM Post Score	-0.239	-0.05	0.963
T1	13.755	2.60	0.009
T2	-1.325	-0.26	0.791
T1 * Task-SMM Post Score	-11.500	-1.30	0.195
T1 * Team-SMM Post Score	-1.832	-0.24	0.811
T2 * Task-SMM Post Score	24.059 *	2.47	0.014
T2 * Team-SMM Post Score	-10.307	-1.39	0.165
R-square:	within = 0.1737 between = 0.0543 overall = 0.1221		
Number of Observation	201		
Wald Test chi2(8)	30.23		
Prob>chi-square	0.0002		
Breusch-Pagan Lagrange Multiplier Test:	Null Hypotheses: Var(u) = 0 Calculated Chi-square(1) = 6.92 Prob > chi-square = 0.0085		
Hausman Specification test:	Null Hypothesis: No systematic difference in coefficients Calculated Chi-square(8) = 8.36 Prob > chi-square = 0.3990		

Notes: Model: Individual Performance = $\beta_0 + \beta_1$ Task-SMM+ β_2 Team-SMM+ β_3 T1 + β_4 T2+ β_5 T1Task-SMM + β_6 T1Team-SMM + β_7 T2Task-SMM+ β_8 T2Team-SMM, *** $p \leq .001$, ** $p \leq .01$, * $p \leq .05$

Growth Score of SMMs Degree (Variance) and Individual Performance

Operational hypothesis 4.2.1 was also examined with the growth scores of Task-SMM Degree (Variance) and Team-SMM Degree (Variance). The Breusch-Pagan Lagrange Multiplier test and the Hausman Specification test justified that the random-effects GLS regression estimation is more appropriate than fixed-effects regression.

Overall, R-square value was 0.0978, thus the variables accounted for approximately 10% of total variance in individual performance. However, there were no statistically significant impacts of the growth scores of Task-SMM Degree (Variance) and

Team-SMM Degree (Variance) on individual performance. The following Table 4.25 shows the results of analysis.

Table 4.25.

Results from Random-Effects GLS Regression of the Growth Scores of Task-SMM Degree (Variance) and Team-SMM Degree (Variance) on Individual Performance

Variable	Coefficient Estimate	Z-statistics	P>abs. Z
Constant	51.783	25.17	0.000
Task-SMM Growth Score	-1.690	-0.31	0.754
Team-SMM Growth Score	-2.682	-0.57	0.572
T1	5.488	2.09	0.037
T2	3.853	1.24	0.214
T1 * Task-SMM Growth Score	2.113	0.33	0.738
T1 * Team-SMM Growth Score	-3.798	-0.69	0.489
T2 * Task-SMM Growth Score	-4.467	-0.60	0.546
T2 * Team-SMM Growth Score	6.784	0.89	0.373
R-square:	within = 0.1534 between = 0.0247 overall = 0.0978		
Number of Observation	201		
Wald Test chi2(8)	24.57		
Prob>chi-square	0.0018		
Breusch-Pagan Lagrange Multiplier Test:	Null Hypotheses: Var (u) = 0 Calculated Chi-square(1) = 6.98 Prob > chi-square = 0.0082		
Hausman Specification test:	Null Hypothesis: No systematic difference in coefficients Calculated Chi-square(8) = 6.35 Prob > chi-square = 0.6086		

Notes: Model: Individual Performance = $\beta_0 + \beta_1 \Delta$ Task-SMM + $\beta_2 \Delta$ Team-SMM + β_3 T1 + β_4 T2 + β_5 T1 Δ Task-SMM + β_6 T1 Δ Team-SMM + β_7 T2 Δ Task-SMM + β_8 T2 Δ Team-SMM, *** $p \leq .001$, ** $p \leq .01$, * $p \leq .05$

In sum, the individual performance score decreased over time as the post score of Task-SMM Degree (Variance) increased. However, at the specific time period from Time 2 to Time 3, the individual performance score increased as the post score of Task-SMM Degree (Variance) increased.

On the other hand, no significant effect of the growth scores of Task-SMM Degree (Variance) and Team-SMM Degree (Variance) on individual performance was revealed.

Therefore, operational hypothesis 4.2.1. was partially supported based on the results.

Operational hypothesis 4.2.2.

4.2.2. As the average score of **Team-SMM Degree** or **Task-SMM Degree** increase, the **individual performance** score will show a statistically significant increase.

Post Score of SMMs Degree (Average) and Individual Performance

Operational hypothesis 4.2.2. was tested with the post scores of Task-SMM Degree (Average) and Team-SMM Degree (Average). The results of the Breusch-Pagan Lagrange Multiplier test and the Hausman Specification test justified the choice of random-effects GLS regression. The regression was used to see how much the increase of the post scores of Task-SMM Degree (Average) and Team-SMM Degree (Average) influence the increase of individual performance.

Overall, the post score of Team-SMM Degree (Average) had significantly positive impacts on the improvement of individual performance score at the 5% significance level. The individual performance score increased by 8.514 points as the post scores of Team-SMM Degree (Average) increased by one point. Also, an increase of one point in Team-SMM Degree (Average) resulted in an increase in the average of individual performance by 10.954 points at the time period from Time 1 to Time 2. The following Table 4.26. shows the summary of the results

Table 4.26.

Results from Random-Effects GLS Regression of the Post Scores of Task-SMM Degree (Average) and Team-SMM Degree (Average) on Individual Performance

Variable	Coefficient Estimate	Z-statistics	P>abs. Z
Constant	34.649	1.55	0.122
Task-SMM Post Score	-4.414	-0.73	0.465
Team-SMM Post Score	8.514*	2.18	0.030
T1	-11.101	-0.46	0.643
T2	-18.833	-0.56	0.578
T1 * Task-SMM Post Score	-7.369	-1.14	0.255
T1 * Team-SMM Post Score	10.954 *	2.13	0.033
T2 * Task-SMM Post Score	7.811	1.03	0.305
T2 * Team-SMM Post Score	-1.934	-0.36	0.718
R-square:	within = 0.1749 between = 0.0440 overall = 0.1187		
Number of Observation	201		
Wald Test chi2(11)	30.22		
Prob>chi-square	0.0002		
Breusch-Pagan Lagrange Multiplier Test:	Null Hypotheses: Var(u) = 0 Calculated Chi-square(1) = 7.29 Prob > chi-square = 0.0069		
Hausman Specification test:	Null Hypothesis: No systematic difference in coefficients Calculated Chi-square (8) = 3.11 Prob > chi-square = 0.9275		

Notes: Model: Individual Performance = $\beta_0 + \beta_1$ Task-SMM+ β_2 Team-SMM+ β_3 T1 + β_4 T2+ β_5 T1Task-SMM + β_6 T1Team-SMM + β_7 T2Task-SMM+ β_8 T2Team-SMM, *** $p \leq .001$, ** $p \leq .01$, * $p \leq .05$

Growth Score of SMMs Degree (Average) and Individual Performance

Operational hypothesis 4.2.2 was also examined with the growth scores of Task-SMM Degree (Average) and Team-SMM Degree (Average). Based on the results of the Breusch-Pagan Lagrange Multiplier Test and the Hausman Specification test, the choice of using random-effects GLS regression was justified. Therefore, the random-effects GLS regression was used to examine how the increase of the growth scores of Task-SMM Degree (average) and Team-SMM Degree (average) have impacts on the increase of individual performance over time. As the result indicated, there were no overall significant impacts of the growth scores of Task-SMM Degree (Average) and Team-SMM Degree

(Average) on individual performance. However, the average of individual performance score increased by 5.893 point as the growth score of Task-SMM Degree(Average) increased by one point at the specific time period from Time 2 to Time 3. The results are summarized in Table 4.27.

Table 4.27.

Results from Random-Effects GLS Regression of the Growth Scores of Task-SMM Degree (Average) and Team-SMM Degree (Average) on Individual Performance

Variable	Coefficient Estimate	Z-statistics	P>abs. Z
Constant	52.468	22.20	0.000
Task-SMM Growth Score	-3.116	-1.20	0.231
Team-SMM Growth Score	4.116	1.55	0.120
T1	4.383	1.19	0.233
T2	1.753	0.54	0.590
T1 * Task-SMM Growth Score	-4.018	-1.29	0.198
T1 * Team-SMM Growth Score	5.711	1.69	0.091
T2 * Task-SMM Growth Score	5.893*	2.05	0.041
T2 * Team-SMM Growth Score	0.199	0.03	0.973
R-square:	within = 0.1964 between = 0.0081 overall = 0.1156		
Number of Observation	201		
Wald Test chi2(8)	31.85		
Prob>chi-square	0.0001		
Breusch-Pagan Lagrange Multiplier Test:	Null Hypotheses: Var (u) = 0 Calculated Chi-square(1) = 8.94 Prob > chi-square = 0.0028		
Hausman Specification test:	Null Hypothesis: No systematic difference in coefficients Calculated Chi-square(8) = 5.28 Prob > chi-square = 0.7272		

Notes: Model: Individual Performance = $\beta_0 + \beta_1 \Delta$ Task-SMM+ $\beta_2 \Delta$ Team-SMM+ β_3 T1 + β_4 T2+ β_5 T1 Δ Task-SMM+ β_6 T1 Δ Team-SMM + β_7 T2 Δ Task-SMM+ β_8 T2 Δ Team-SMM, *** $p \leq .001$, ** $p \leq .01$, * $p \leq .05$

Based on the results of the influences of the post scores and growth scores of Task-SMM Degree (Average) and Team-SMM Degree (Average) on individual performance, operational hypothesis 4.2.2 was partially supported.

Summary of the Best Predictor in Team and Individual Performance over Time

In conclusion, team performance was not affected by Task-SMM Structure or Team-SMM Structure. However, as expected, team performance decreased as the post score of Task-SMM Degree (Variance) increased at the specific time period from Time 2 to Time 3. It implies that team members' similar perceptions on their task knowledge and team environment was necessary to accomplish their project at the end of project. Also, team performance increased as the post score of Task-SMM Degree (Average) increased, which means team members' highly shared perceptions on task knowledge and team environment improved their team performance. One of interesting findings is that team performance increased as the post score of Task-SMM Degree (Average) increased. However, team performance decreased as the post score of Team-SMM Degree (Average) increased from Time 1 to Time 2. Moreover, team performance also decreased as the growth score of Team-SMM Degree (Average) increased from Time 1 to Time 2.

On the other hand, individual performance scores decreased as the growth score of Team-SMM Structure increased over time. However, individual performance increased as the post score and the growth score of Team-SMM Structure increased from Time 2 to Time 3. Also, the individual performance score decreased as the post score of Task-SMM Degree (Variance) increased over time; however, it increased as the post score of Task-SMM Degree (Variance) increased at the specific time period from Time 2 to Time 3. Lastly, individual performance increased as the post score of Team-SMM Degree (Average) increased over time. Also, the increases of the post score of Team-SMM (Average) and the growth score of Task-SMM (Average) led to the increase of individual performance from Time 1 to Time 2 and from Time 2 to Time 3 respectively. The summary of results is presented in Table 4.28., and the results are discussed in Chapter V.

Table 4. 28.

Summary of the Tested Hypotheses and Results

SMM			Task- SMM	Team- SMM	T1 * Task- SMM	T1 * Team- SMM	T2 * Task- SMM	T2 * Team- SMM
TP ^a	Structure	Post Score	ϕ	ϕ	ϕ	ϕ	ϕ	ϕ
		Growth Score	ϕ	ϕ	ϕ	ϕ	ϕ	ϕ
	Degree (Variance)	Post Score	ϕ	ϕ	ϕ	ϕ	-	ϕ
		Growth Score	ϕ	ϕ	ϕ	ϕ	ϕ	ϕ
	Degree (Average)	Post Score	+	ϕ	+	-	ϕ	ϕ
		Growth Score	ϕ	ϕ	ϕ	-	ϕ	ϕ
IP ^b	Structure	Post Score	ϕ	ϕ	ϕ	ϕ	ϕ	+
		Growth Score	ϕ	-	ϕ	ϕ	ϕ	+
	Degree (Variance)	Post Score	-	ϕ	ϕ	ϕ	+	ϕ
		Growth Score	ϕ	ϕ	ϕ	ϕ	ϕ	ϕ
	Degree (Average)	Post Score	ϕ	+	ϕ	+	ϕ	ϕ
		Growth Score	ϕ	ϕ	ϕ	ϕ	+	ϕ

Notes: a: Team Performance, b: Individual Performance, +: statistically significant increase, -: statistically significant decrease, ϕ : no statistically significant results

CHAPTER V: DISCUSSION

INTRODUCTION

The purpose of this study is to investigate how shared mental models change over time and how the changes affect team and individual performance in students' manufacturing engineering teams. Shared mental models were measured in terms of Team-SMM and Task-SMM. Based on Mohammed, Klimoski, and Rentsch's (2000) suggestions that shared mental models should be measured in terms of their structure and content, each Team-SMM and Task-SMM was measured in Team-SMM Structure, Team-SMM Degree, Task-SMM Structure and Task-SMM Degree. The influence of Team-SMM Structure, Team-SMM Degree, Task-SMM Structure and Task-SMM Degree on team performance and individual performance was respectively examined over time to determine their unique influences on team and individual performance in the process of a complex team project.

The overall findings are discussed with two main research questions: (1) Does SMM (Team-SMM and Task-SMM) change over time? and (2) Is Team-SMM or Task-SMM the better predictor of team and individual performance? The first research question was answered by using one-way repeated measures ANOVA. The second research question was divided into the following two research questions: (a) Does Team-SMM or Task-SMM predict team performance? If so, how well do they predict team performance over time? and (b) Does Team-SMM or Task-SMM predict individual performance? If so, how well do they predict individual performance over time? To answer these questions, random-effects GLS regression or fixed-effects regression was selectively employed based on the results of the Breusch-Pagan Lagrange Multiplier test and the Hausman Specification test, and the findings are discussed in this chapter. Overall limitations, implications of this study and future studies are also presented at the end of this chapter.

1. Does SMM change over time?

One main research concern for this study was to investigate if SMM changes over time, and if it changes, how the Team-SMM or Task-SMM changes over time. Specifically, the SMMs Structure similarity scores and the average scores of team members' perception ratings on Team-SMM and Task-SMM (SMMs Degree) questionnaires were expected to increase, and the variance (standard deviation) scores of team members' perception ratings was expected to decrease over time. The findings are very interesting. A detailed discussion on the findings is presented in the following sections.

Change of Team-SMM

The change of Team-SMM was measured in terms of the changes of Team-SMM Structure and Team-SMM Degree. The Team-SMM Degree was divided into a variance score and an average score. The variance score and average score indicate respectively the standard deviation and the average score of team members' perception ratings on Team-SMM Degree questionnaires. Each score of those variables was also taken from their post score and growth score in each of the three phases. Namely, the post score and growth score of Team-SMM Structure, the post score and growth score of Team-SMM (Variance), and the post score and growth score of Team-SMM (Average) were respectively considered for each of the three phases, and one-way repeated measures ANOVA analysis was used to investigate their changes across the three phases.

Unlike the results of Mathieu et al., (2000) which found that time did not significantly affect the convergence of shared mental models, the similarity of Team-SMM Structure significantly increased statistically from Time 1 to Time 2, but there was no significant change from Time 2 to Time 3. The possible explanation of why Mathieu et al.'s (2000) study and the present study showed different results is that Mathieu et al.'s (2000) study investigated two-person teams of undergraduates interacting in a single session between 2.5 and 3 hrs while the participants in this study were given one week to complete each of the three subtasks. Thus, Mathieu et al.'s (2000) experiment may not have lasted long enough to detect significant changes in Team-SMM.

On the other hand, the result of this current study is similar to the results of Espinosa and Carley's (2001) study. Team-SMM increased moderately from Time 1 to Time 2 and then, though not significant, decreased slightly from Time 2 to Time 3, supporting the hypothesis that once team members share team-related knowledge such as each others' strengths, weaknesses, skills and abilities, there is not much change in Team-SMM.

In terms of the change of the perceptions on Team-SMM, Team-SMM Degree (Average) significantly increased while Team-SMM Degree (Variance) did not show any significant change from Time 1 to Time 2. Also, the growth score of Team-SMM Degree (Average) decreased implying that the degree of increase in team members' perceptions on Team-SMM at Time 1 was higher than the degree of increase at Time 2. However, the other variables such as the growth score of Team-SMM Structure and the post and growth scores of Team-SMM Degree (Variance) showed no statistically significant change. Based on the significant results in this study, it can be interpreted that team members significantly developed Team-SMM Structure and their perceptions on Team-SMM consisted of teammate knowledge and team interaction information from Time 1 to Time 2. This result is similar to the findings of Lewis's (2004) study that interpersonal communication patterns developed early in a team's collaboration. Also, Tuckman (1965) reported that studies of team development showed that good interpersonal relationships between team members must be established before the team members are able to focus effectively on their given tasks.

At the time period from Time 2 to Time 3, the post score of Team-SMM Degree (Average) increased while other variables did not show any statistically significant changes. The increase of the post score of Team-SMM Degree (Average) indicates that team members developed a highly-shared perception on teammate knowledge and team interaction from Time 2 to Time 3. Considering the results that the post score of Team-SMM Degree (Average) also increased from Time 1 to Time 2, the shared perception on Team-SMM continuously increased from Time 1 to Time 3. This result contradicts the results of Leversque, Wilson and Wholey (2001). They used a questionnaire to measure the perception on Team-SMM, but they found Team-SMM actually decreased over time.

Change of Task-SMM

Like the investigation of the change of Team-SMM, the change of Task-SMM was also investigated in three time periods. It was measured in terms of the post score and growth score of Task-Structure and the post score and growth score of Task-SMM Degree.

At the time period from Time 1 to Time 2, the post score of Task-SMM Structure decreased. This result is contrary to the corresponding hypothesis and it is also contrary to the results in Team-SMM Structure at the same time period. Namely, Task-SMM Structure decreased while Team-SMM Structure increased. This result implies that team members increased the similarity of Team-SMM Structure more than the similarity of Task-SMM Structure at the beginning of the team project (from Time 1 to Time 2).

In terms of the change of team members' perceptions on Task-SMM Degree, the Task-SMM Degree (Average) increased as expected in the hypotheses. This result indicates that team members' perceptions on Task-SMM consisting of task knowledge and team environment increased from Time 1 to Time 2.

At the time period from Time 2 to Time 3, the post score of Task-SMM Degree (Average) increased and the post score of Task-SMM Degree (Variance) decreased as expected in the hypotheses. However, other variables did not significantly change. The results indicate that team members' perceptions on Task-SMM consisting of task knowledge and team environment increased at the end of their team project (from Time 2 to Time 3). Overall, team members' perceptions on Task-SMM increased throughout the performance on their team project (from Time 1 to Time 3). This result is similar to the result of Espinosa and Carley (2001) who found that team members' perceptions on Task-SMM increased steadily and significantly over the given period.

In sum, these results demonstrate that the perception on both Team-SMM and Task-SMM increased over time; however, the structures of Team-SMM and Task-SMM changed at the beginning of the team project (from Time 1 to Time 2). Namely, the Team-SMM Structure increased while the Task-SMM Structure decreased. However, the structures of Team-SMM and Task-SMM did not change from Time 2 to Time 3. The possible explanation is that the structures had been already fully shared at the beginning of

the team project so that the team members would not need to share them further. According to Cannon-Bowers and Salas (2001), a shared mental model is resistant to change if it is formed enough to accomplish the given task.

On the other hand, only the growth score of Team-SMM Degree (Average) significantly decreased among the other growth scores at the time period from Time 1 to Time 2. This result reveals that the team members shared relatively high perceptions on Team-SMM (teammate knowledge and team interaction) at Time 1 and the degree of growth in the perception on Team-SMM decreased at Time 2.

Overall, shared mental models changed over time but the changes of Team-SMM and Task-SMM happened differently depending on the specific time period of the team project and whether its structure or degree was measured. The results support the empirical evidence of many researchers' suggestions that teams go through different processes when they deal with a complex team project, and dynamic changes of Team-SMM and Task-SMM are expected depending on the task and team demands in the team project process (e.g., Marks, Sabella, Burke, & Zaccaro, 2002; Mathieu, Heffner, Goodwin, Salas, & Cannon-Bowers, 2000; McIntyre & Salas, 1995; Fiore, Salas, Cuevas, & Bowers, 2003).

2. Is Team-SMM or Task-SMM the better predictor of performance?

This study assumed that Team-SMM and Task-SMM have unique influences on team and individual performance. It was also assumed that their unique influences will be different depending on the specific time period of a complex team project. In previous studies, some researchers found significant relationships between Team-SMM and team performance but not between Task-SMM and team performance (e.g., Leversque, Wilson and Wholey, 2001; Mathieu, Heffner, Goodwin, Salas, & Cannon-Bowers, 2000). Others found that Team-SMM is less predictive of performance than Task-SMM (e.g., Mathieu, Heffner, Goodwin, Cannon-Bowers, & Salas, 2005). Moreover, Lim and Klein (2006) found that both Team-SMM and Task-SMM were significantly positively related to team performance. In this study, the relationships between SMMs and team performance and between SMMs and individual performance and how these relationships change over time were examined by the random-effects GLS regression or fixed-effects regression analyses.

SMMs Structure and Performance

With regard to the relationships between SMMs Structure and team/individual performance, individual performance was affected by Team-SMM Structure while team performance was not influenced by either Team-SMM Structure or Task-SMM Structure. Overall, individual performance decreased as the growth score of Team-SMM Structure increased over time.

Unlike the study of Mathieu et al.(2000) who found that Task-SMM did not correlate significantly with team performance but that Team-SMM was closely related to team performance, team performance was not affected by either Task-SMM Structure or Team-SMM Structure over time in the present study. On the other hand, individual performance was not affected by either Task-SMM Structure or Team-SMM Structure at the specific time period from Time 1 to Time 2. However, from Time 2 to Time 3, individual performance increased as the post score and growth score of Team-SMM Structure increased. This implies that teams need to reduce the growth score on their sharedness

about teammate knowledge and team interaction information over time, but they should have a high sharedness of Team-SMM Structure at the end of the project to improve their individual performance.

SMMs Degree (Variance) and Performance

In terms of the relationships between SMMs Degree (Variance) and team/individual performance, overall, individual performance decreased as the post score of Task-SMM Degree (Variance) increased over time.

At the specific time period from Time 1 to Time 2, team performance and individual performance were not affected by either Task-SMM Degree (Variance) or Team-SMM Degree (Variance). However, at the specific time period from Time 2 to Time 3, team performance and individual performance showed the opposite results. Namely, individual performance increased as the post score of Task-SMM Degree (Variance) increased; however, team performance decreased as the post score of Task-SMM Degree (Variance) increased. This shows how team performance and individual performance were affected differently by Task-SMM Degree (Variance) from Time 2 to Time 3. The results also imply that a highly-shared mental model on task knowledge and team environment is important to improve team performance. In contrast, the diverse mental models of task knowledge and team environment are important to enhance individual performance at the end of the project (from Time 2 to Time 3).

SMMs Degree (Average) and Performance

Lastly, the results show interesting relationships between SMMs Degree (Average) and team/individual performance. Overall, a highly-shared perception on Task-SMM is a dominant factor to increase team performance while a highly-shared perception on Team-SMM is an important factor to improve individual performance over time. There are some possible reasons why the Task-SMM Degree (average) and Team-SMM Degree (average) showed different relationships with team performance.

A possible reason may be related to the measurement of team performance. In this

study, team performance was measured by their team projects which focused on task-related knowledge. If the team performance measurement included team-related ability or knowledge, the results might be different. Second, it is suggested that Task-SMM is a more predictive factor of team performance than Team-SMM in performing a team project that requires a relatively short period of time (Lim & Klein, 2006). Due to the limited time period to accomplish the team project, it might be difficult for team members to fully share Team-SMM which consists of teammate knowledge and team interaction. The process of sharing Team-SMM may be rather detrimental in performing their projects.

At the specific time period from Time 1 to Time 2, team performance increased as the post score of Task-SMM Degree (Average) increased while it decreased as the post and growth scores of Team-SMM Degree (Average) increased. Namely, team performance had a positive relationship with the post score of Task-SMM; however, it had a negative relationship with the post and growth scores of Team-SMM. On the other hand, individual performance had a positive relationship with Team-SMM over time and the positive relationship was specifically important at the time period from Time 1 to Time 2. This implies that highly-shared perceptions on teammate knowledge and team interactions are important to enhance individual performance at the beginning of the team project. The possible reason why Team-SMM is positively associated with individual performance is that individuals belonged to their team and they were involved in team cognitive processes. Even though individual performance was measured by individual team members, their perceptions may be affected by the team project on which they worked. This result also supports that individual team member's thinking process cannot be separated from the team thinking process as long as the individual belongs to a team (Cooke et al., 2004).

At the specific time period from Time 2 to Time 3, team performance was not affected by either Team-SMM Degree (Average) or Task-SMM Degree (Average). However, individual performance increased as the growth score of Task-SMM Degree (Average) increased at the end of the team project (from Time 2 to Time 3). This implies that increasing the growth score of Task-SMM perception is important to accomplish their given task and also to improve their individual performance at the end of the project.

Summary

The results of this study contribute to both current theory and empirical research fields by providing empirical findings. The results of this study provide some insights into the existence of the dynamic relationships of shared mental models (Team-SMM or Task-SMM) and team/individual performance. These results also have provided several interesting findings about the influences of Team-SMM and Task-SMM on team and individual performance over time.

First, it was revealed that individual performance was affected by Team-SMM. Highly shared perceptions on Team-SMM lead to the improvement of individual performance. Many students tend to focus on their own tasks to improve their individual performance even when they belong to a team. However, according to Latane's (1981) social impact theory, individuals' cognition and behaviors are changed by the presence or action of other team members when they work as a team. Thus, their individual performance may be affected by how well the team members know other team members and interact with them. Therefore, it will be important to recognize that an isolated individual working without collaborating with other team members will not help improve his/her individual as well as team performance.

Second, the results of this study suggest that team members should have a highly shared perception on Task-SMM to improve team performance, but a diverse perception on Task-SMM is necessary to improve individual performance at the end of the team project. This implies that a highly shared task knowledge and team environment is important to improve team performance, but it does not necessarily improve individual performance. According to Stout, Cannon-Bowers, Salas, & Milanovich (1999), critical decisions are made by teams of individuals who must coordinate their activities and share their final opinions to achieve effectiveness. Therefore, a highly-shared perception on Task-SMM is closely associated with the enhancement of team performance, and having a high similarity of Task-SMM is critically important at the end of the team project when team members have to finally reach a conclusion.

Third, team members need to understand the underlying mechanism that explains

the dynamic relationships between SMMs and performance. Also, they need to adaptively build appropriate SMMs depending on task and team demands at the specific time periods of the team project. The findings in this study may lead to some of the following questions: what is the typical mechanism of the dynamic relationships between SMMs and performance; what is the appropriate level of similarity of Team-SMM and Task-SMM to improve team and individual performance; and how can team-based instruction be designed based on the mechanism?

LIMITATIONS OF THE STUDY

Even though this study provided many significant results and useful insights for future studies, several limitations exist with respect to this research effort. Some of the limitations are associated with the practical difficulties in conducting a large sample study on shared mental models in a specific content domain at school settings, and other limitations are related to the fact that the research area of shared mental models is still developing (Fiore, & Salas, 2004). From the theoretical definition of shared mental models to its practical measurement, this research field should continue to be studied to build a solid foundation for the concept of shared mental models, its factors, and measurement techniques.

First, the sample size was one of limitations of this study. The participants for this study were 67 students consisting of 33 teams. Because of using real engineering classes for this study, the study was conducted twice in the same course in different semesters. The course was only offered every spring semester and less than 45 students usually registered for the course. Therefore, the 43 students and 30 students, respectively participated in the study in Spring 2006 and Spring 2007. The sample size was relatively small so it limited the power of the statistical analyses. However, the sample size was calculated based on Green's (1991) formula which produces a reliable prediction equation and takes estimates of effect sizes into consideration. Also, the task provided to students in this study was very unique and specific to engineering, so that it was hard to find the same classes and similar

populations for this study. Therefore, large sample sizes would be needed to get more stable and statistically significant results in future studies.

Second, using Pathfinder to measure the structure of shared mental models, and a Likert-scale questionnaire to measure the degree (content) of shared mental models, can be another limitation in this study. Among many measurement techniques, the Pathfinder and Likert-scale questionnaire were selected to measure the structure and degree of shared mental models. Even though many measurements (e.g., Pathfinder, observation, concept map, similar ratings and Likert-Scale questionnaires) have been discussed in terms of their advantages and disadvantages (Langan-Fox et al., 2000), there is no consensus as to which measurement is more appropriate (Mohammed, Klimoski, & Rentsch, 2000). Therefore, the Pathfinder and Likert-scale questionnaire were chosen because the Pathfinder provides more comprehensive measurement techniques (Langan-Fox et al., 2000; Mohammed et al., 2000), and the Likert-scale questionnaire was selected based on its time-efficiency requiring little reading, writing, or verbalization (Langan-Fox et al., 2000). The questionnaire also supports the theoretical rationale underlying the conception of the shared mental model which consists of Task-SMM and Team-SMM. For future studies, using mixed measurement techniques to measure shared mental models would be needed as suggested by Kraiger and Wenzel (1997). Further, developing more reliable and valid instruments will be necessary in the area of shared mental models. Also it will be interesting if the instruments could measure the structure and degree of shared mental models at the same time and instantly visualize the change of shared mental models and its relationship to team and individual performance. It may be useful for team members to self check their current level of sharedness and adaptively respond to the changes.

Third, the size of team can be raised as one of the limitations of this study. Considering the definition of team and the power of statistical analysis, each team consisted of two team members and one team had three team members. According to Salas, Dickinson, Converse, and Tannenbaum (1992), the team is defined as “two or more people who interact dynamically, interdependently and adaptively toward a common and valued goal, who have been assigned specific roles or functions to perform, and who have a limited

life-span of membership” (p.4). The number of team members was also decided based on the number of roles which are necessary to perform each team project. Moreover, small team size might be more appropriate than large team size in performing a team project that requires a relatively short period of time as in this study. However, the small team size could require relatively few communications and easily build a shared mental model compared with teams that consist of more than two or three team members (Rentch & Klimoski, 2001). Therefore, it will be necessary to conduct a similar study with teams that have more than two team members to see a more dynamic change of shared mental models. It will be also interesting if a study is conducted to investigate how many team members are the most appropriate in building a shared mental model and improving team and individual performance.

IMPLICATIONS

This study provides several important theoretical and practical contributions to the area of shared mental models and performance. First, this study employed a panel data analysis because the data was collected over time and with the same individuals. Specifically, a random-effects GLS regression and fixed-effects regression were selectively used based on the results of the Hausman Specification test and the Breusch-Pagan Lagrange Multiplier test. Due to the consideration of panel data in nature, a random-effects GLS regression and fixed-effects regression was more appropriate than conducting multiple regressions per each time point. Through the random-effects GLS regression or fixed-effects regression analysis, it was possible to identify the time point when Team-SMM or Task-SMM mainly influenced team and individual performance during a complex team project.

Second, this study measured the structure and degree of shared mental models at the same time while previous studies focused on either the structure or the degree of shared mental models. Shared mental models are generally defined as the degree of convergence among team members with regard to the content of known types of shared mental models

and the relationships between the types (Cannon-Bowers & Salas, 2001; Cannon-Bowers, Salas, & Converse, 1993; Klimoski & Mohammed, 1994). Thus, it was appropriate to measure both the structure and degree of shared mental models in examining the change of Team-SMM or Task-SMM and their relationships with team and individual performance.

Third, this study conducted more comprehensive measures of shared mental models. A large number of empirical studies show a limitation in dealing with two types of shared mental models: task-related knowledge and team-related knowledge. As a result, the meaning of shared mental models can be reduced to things related to either the team- or the task-related knowledge. In fact, various types as well as team- and task-related knowledge should be considered in complex problem-solving (Eccles & Tenenbaum, 2004; Cooke et al, 2000, Mohammed, Klimoski & Rentsch, 2000, Cannon-Bowers et al 1993). This is because team members can successfully solve a complex problem when they have a shared mental model of diverse factors. Therefore, this study included Task-SMM which consists of task knowledge and team environment and Team-SMM which consists of teammate knowledge and team interaction in measuring shared mental models for this study.

Fourth, this study fulfilled the need of the shared mental model studies in the field of a manufacturing engineering education. According to Langan-Fox, Anglim, and Wilson (2004), there have been no substantial efforts to study teams of students in educational settings. In particular, manufacturing engineering education deals with many complex problems and requires teams of students to work together to find solutions to the complex problems. In order to understand how to improve team performance as well as individual performance in the manufacturing engineering education field, it is necessary to conduct studies to uncover the mechanism of shared mental models and its effect on performance. With regard to this, this study contributes to these needs.

Fifth, this study also investigated the relationship between shared mental models and individual performance. Many researchers tend to focus on the shared mental model and its effect on team performance (Griepentrog & Fleming, 2003; Kraiger & Wenzel, 1997; Rouse, Cannon-Bowers, & Salas, 1992). There is a lack of studies on the relationships between shared mental models and individual performance. However, shared

mental models can affect individual performance because shared mental models and individual mental models are closely interwoven (Cooke et al., 2004). Therefore, this study contributed to the investigation and revealed that shared mental models positively affect individual performance.

FUTURE RESEARCH

Future research needs to conduct various experimental studies based on the results of this study in order to establish a robust theoretical framework of shared mental models. Specifically, future research needs to move in the following four directions. First, it will be interesting to extend this study to online team-based learning environments. Unlike learning in the same place and time with others, online learners have to express their thoughts by interacting with computer-mediated protocols such as web bulletin boards and e-mail. Thus, if learners study in online team-based learning environments, it could be very difficult for them to negotiate the meaning and to construct a shared mental model necessary for effective team-based learning. Therefore, future research should continue to explore how shared mental models change over time and how they influence team and individual performance in online team-based learning. The findings of future studies will be able to suggest ways to design effective and efficient online learning environments.

Second, future research should start to investigate if there is a typical mechanism explaining the dynamic relationship between shared mental models and performance in spite of different levels of task difficulty, different types of tasks, and different numbers of team members. If the typical mechanism does not exist, it will be worthwhile to study how differently Team-SMM and Task-SMM change over time and how their changes affect team and individual performance depending on different levels of task difficulty, different types of tasks, and a different number of team members. Ultimately, the results of these studies will provide more accurate and appropriate findings to help design team-based instructions.

Third, it is necessary to measure the accuracy of shared mental models in future studies. Even though this study focused on the investigation of the change of the similarity

of shared mental models and its relationships with team and individual performance, the accuracy of shared mental models and its relationships with performance will be interesting in future studies. In fact, a highly-shared mental model does not mean that team members have an accurate shared mental model because team members can have an incorrect shared mental model (Mathieu et al., 2000). Therefore, future studies are needed to measure the accuracy of shared mental models and investigate its relationship with team and individual performance.

Fourth, future studies should focus on making better team-based instructions based on the current findings from this study. The current findings suggest that team-based instructions should seek not only to improve Task-SMM but also to enhance Team-SMM. Because such team-based instruction has typically focused on the enhancement of task-related skills (Morgan, Salas, & Glickman, 1993), it is suggested that team-based instructions would be improved by the inclusion of elements specifically aimed at the development of teamwork skills. Moreover, team-based instruction should include how team members can adaptively share Team-SMM and Task-SMM depending on task and team demands.

In a broader sense, it will be important to summarize all the previous empirical findings in shared mental model studies. Moreover, it will be necessary to design online and offline team-based instructions based on the Meta studies. No matter how many empirical studies reveal the change of shared mental models and its relationship with performance, it would not be useful if the results cannot be applied to enhance real educational settings. Therefore, there should be practical efforts to design and develop team-based instructions to improve team and individual performance using the results of many empirical studies.

CONCLUSIONS

There were a number of objectives for this study. The first purpose of this study was to examine the change of shared mental models in terms of Team-SMM Structure, Team-SMM Degree, Task-SMM Structure and Task-SMM Degree. The second goal was to find which types of shared mental models have statistically-significant effects on team and individual performance over time. This study assumed that Team-SMM and Task-SMM have unique influences on team and individual performance. It was also assumed that their unique influences will change depending on task and team demands in the specific time periods of the team project.

First, the results of this study supported that shared mental models (Team-SMM and Task-SMM) change over time. In terms of the change of Team-SMM, the post score of Team-SMM Degree (Average) increased from Time 1 to Time 3. At the specific period from Time 1 to Time 2, the post score of Team-SMM Structure increased and the growth score of Team-SMM Degree (Average) decreased. In terms of the change of Task-SMM, the post score of Task-SMM Degree (Average) increased from Time 1 to Time 3. At the specific time period from Time 1 to Time 2, the post score of Task-SMM Structure significantly decreased. Interestingly, Team-SMM Structure increased while Task-SMM Structure decreased from Time 1 to Time 2. The post score of both Team-SMM Degree (Average) and Task-SMM Degree (Average) increased over time (from Time 1 to Time 3). This implies that Team-SMM and Task-SMM changed over time and the changes happened differently depending on measuring the structure and degree of shared mental models.

Second, Team-SMM and Task-SMM were associated with team and individual performance. It was assumed that Team-SMM and Task-SMM would have unique influences on team and individual performance and the influences would vary depending on task and team demands at the specific time periods of the team project. The results of this study supported these assumptions.

At the time period from Time 1 to Time 2, Task-SMM Degree (Average), that is, a

highly shared perception of Task-SMM (task knowledge and team environment), positively influenced the improvement of team performance, while a highly-shared perception about Team-SMM (teammate and team interaction) lead to the improvement of individual performance.

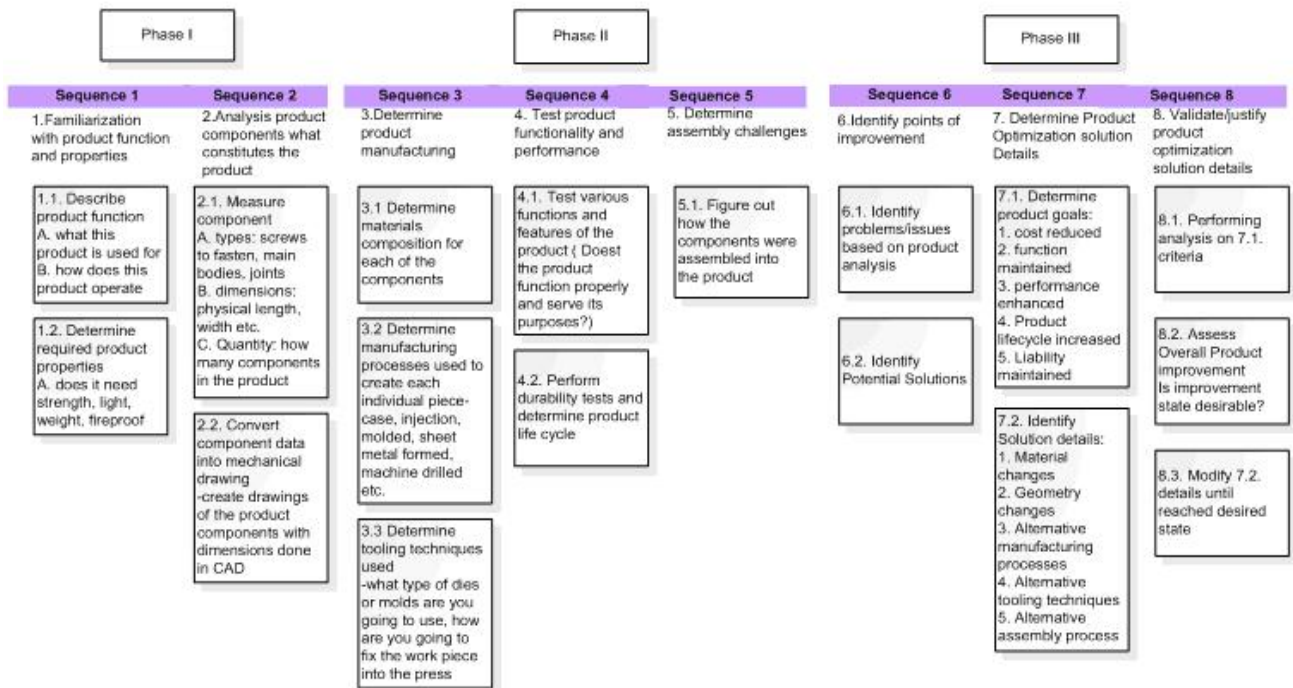
At the time period from Time 2 to Time 3, team performance decreased as the variance of the perception of Task-SMM (task knowledge and team environment) increased. This result implies that team members need to have a highly-shared perspective about the given task and team environment to accomplish their team project successfully at the end of the team project. According to Lim and Klein (2006), Task-SMM may be more predictive of performance than Team-SMM in a team project that requires a relatively short period of time. This is because team members do not have enough time to share teammate knowledge and team interaction information facing urgent team tasks. Unlike team performance, diverse perceptions on Task-SMM positively affected the improvement of individual performance at the time period from Time 2 to Time 3; that is, diverse perceptions on task knowledge and team environment are necessary to increase individual performance at the end of the team project.

This research adds to the growing literature by empirically examining the relationships between shared mental models and team performance (Mathieu et al., 2000; Lim & Klein, 2006). Moreover, it was a new attempt to investigate the relationship between shared mental models and individual performance. It was revealed that individual performance was affected by Team-SMM consisting of teammate knowledge and team interaction. In performing as a team, some students tend to work independently even through they are expected to work together. However, the results showed that all individuals in a team should actively work together sharing their teammate knowledge and team interaction and thus leading to the improvement of individual performance.

Overall, the findings of this study are particularly important because they contribute to evidence that Team-SMM and Task-SMM change over time, and they have unique influences on team and individual performance. Moreover, the unique influences varied depending on the specific time period of the team project. Thus, this study revealed

the underlying mechanism which explained the dynamic relationship between shared mental models and performance over time. However, this study should be replicated with a larger sample size, using mixed methods to measure shared mental models, and teams that have more than two team members. Based on the results of this study, future studies are expected to be conducted in the following directions. First, they should focus on building a strong foundation of shared mental model research fields through theoretical and empirical studies on factors, measurement techniques, and the relationship with performance. Second, research on developing a computer simulation program or any supporting tool which can automatically display the change of shared mental models and the relationship with team and individual performance should be conducted. This will help students to diagnose their process in the team project and adjust their teamwork and task work appropriately. Third, it will be interesting to extend the shared mental model studies to online team-based learning situations and to conduct similar studies while considering other variables such as the different levels of task difficulty, different types of tasks and different numbers of team members. Fourth, the unveiled underlying mechanism of the dynamic relationship between shared mental models and performance should be considered in designing online and offline instructions in complex team-based learning. The instructions could support team members to accomplish their team project effectively and efficiently. Specifically, they will be able to help team members to understand what is going on with the task and to easily anticipate what may happen next as well as which actions they need to take to improve team and individual performance.

APPENDIX A. TASK ANALYSIS



APPENDIX B. TEAM PROJECT: PHASE I, II, III

Phase I

Required Contents

- Product description, including target properties
- Working principle of product
- Breakdown of components, including a drawing (either hand-sketched or CAD-generated; CAD is preferred, of course!) for each component

NOTE:

You will need to perform some type of functionality or durability test later on. When you take the product apart, make sure that you will be able to re-assemble it to its original condition. Otherwise, perform the test(s) first before taking it apart.

Phase II

Required Contents

- Material description for each component
(What type of material is each component made from? Be as specific as possible. “Plastic”, “metal”, “ceramic”, etc. are not sufficient.)
- Manufacturing processes used to fabricate components (Use various references, including books, journals, technical publications, websites, etc.)
- Assembly procedure (Explain the complete sequence of component assembly.)
- Automation, DFA, and DFD considerations

Phase III

Required Contents

- Design improvement
- Perform durability tests
- Perform functionality tests
- Identify problems with current design (i.e. in terms of material selection, geometry, manufacturing processes, tooling, DFA, DFD, product performance, costs, etc.)
- Propose new design(s) that address the problems identified (Brainstorming will be a useful tool here.)
- Make free-hand sketch or CAD-generated drawing of the new design (Seeing is believing!)
- Justify your design proposal

APPENDIX C. DEMOGRAPHIC SURVEY

SSN (Last 4 digits): _____ Team #: _____

Please complete to following questions by either filling in the blanks or circling the correct response.

1. Background Information

1.1 Age: _____

1.2 Gender: a) Female, b) Male

1.3 Race: a) Asian, b) Black, c) Caucasian, d) Hispanic, e) Native American, f) Other _____

1.4. Years in school: a) Junior, b) Senior

1.5 If you transfer your major, what major did you study?

- a) Mechanic Engineering b) Civil and Environmental Engineering
 c) Electronic Engineering d) Chemical Engineering e) Other major _____

2. Task Experiences

2.1 Do you have any previous experience regarding your team project? a) Yes b) No

If, yes, briefly explain your experience(s) regarding your team project:

	Very Low	Low	Medium	High	Very High
2.2 What is your task skill level on your team project (product design, analysis and/or improvement)?	1	2	3	4	5
2.3 What is your team's task skill level on your team project (product design, analysis and/or improvement)?	1	2	3	4	5

3. Team Experiences

3.1 Do you have prior experience(s) working with your partner before?

a) Yes b) No

If yes, briefly explain your prior experience(s) working with your partner:

	Very Low	Low	Medium	High	Very High
3.2 What is your ability to work successfully as a team?	1	2	3	4	5
3.3 What is your partner's ability to work successfully as a team?	1	2	3	4	5

APPENDIX D. TEAM-SMM STRUCTURE: PHASE I, II, III

SSN (Last 4 digits): _____ Team #: _____

Directions: Below are several characteristics associated with the interactions that typically occur between team members.

Role/Responsibility—usual or expected function of a given team member, the tasks for which a team member is accountable.

Information Sources—place(s) (person, books, and resources) where the team can get information related to tasks.

Interaction Patterns—common communication between or joint activity involving team members.

Communication Channels—ways (modes) that the team uses to communicate.

Role Interdependencies—relying on mutual assistance, support, cooperation, or interaction among team members' roles.

Information Flow—degree (freely vs. constrained) of information movement among team members.

Teammates' Knowledge—general awareness or possession of information, facts, ideas, truths, or principles of your team members.

Teammates' Skill—general team members' ability to do something well, usually gained through experience and training.

Teammates' Attitudes—team members' opinion or general feeling about something.

Teammates' Preferences—team members' views that a particular course of action is more desirable than another.

Teammates' Tendencies—the way that team members typically behaves or are likely to react or behave.

At this point of the team project, please rate the relatedness of each of the following characteristics in the boxes below. For example, in the upper left-hand square you are asked to indicate how similar **Information Source** is to **Role/Responsibility**.

-4	-3	-2	-1	0	1	2	3	4
Negatively Related: A high degree of one requires a low degree of the other. Having a lot of one means you must have very little of the other				Totally unrelated				Positively Related: A high degree of one requires a high degree of the other. Having a lot of one means you must have a lot of other as well

	Information Sources	Interaction Patterns	Communication Channels	Role Interdependence	Information Flow	Teammates' Knowledge	Teammates' Skill	Teammate's Attitudes	Teammate's Preferences	Teammate's Tendencies
Role/Responsibility										
Information Sources										
	Interaction Patterns									
	Communication Channels									
		Role Interdependencies								
			Information Flow							
				Teammates' Knowledge						
					Teammates' Skill					
						Teammate's Attitudes				
							Teammate's Preferences			

APPENDIX E. TEAM-SMM DEGREE: PHASE I, II, III

SSN (Last 4 digits): _____ Team #: _____

This questionnaire involves rating and describing how you perceive your team member as well as yourself based on your perceptions prior to working with your partner on the course project. Please rate the following statements by circling the number the best describes your level of agreement. (1=strongly disagree and 5= strongly agree)

Part II: Team-SMM						
Statements		Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree
Team Interaction	1 My team understands its roles and responsibilities.	1	2	3	4	5
	2 My team knows where it can get information.	1	2	3	4	5
	3 My team understands interaction patterns.	1	2	3	4	5
	4 My team understands how they can exchange information for doing various team tasks.	1	2	3	4	5
	5 My team can adopt flexibly to any roles within the team.	1	2	3	4	5
	6 My team is likely to make a decision together.	1	2	3	4	5
	7 My team communicates with other teammates while performing team tasks.	1	2	3	4	5
	8 My teammates informally communicate with one another throughout various team tasks.	1	2	3	4	5
	9 My teammates consistently demonstrate effective listening skills.	1	2	3	4	5
Teammate knowledge	10 My teammate has a general knowledge of specific team tasks.	1	2	3	4	5
	11 My teammate knows specific strategies for completing various tasks.	1	2	3	4	5
	12 My teammate knows the general process involved in conducting a given task.	1	2	3	4	5
	13 My teammate understands the skills necessary for doing various team tasks.	1	2	3	4	5
	14 My teammate communicates with other teammates while performing team tasks.	1	2	3	4	5
	15 My teammate supports continuous improvement in terms of personal skills as well as overall team skills.	1	2	3	4	5
	16 I have a good knowledge about my teammates' attitudes.	1	2	3	4	5
	17 There is a sense of cohesion and cooperation among my teammates.	1	2	3	4	5
	18 My teammate takes pride in his/her work.	1	2	3	4	5
	19 I have a good knowledge about my teammates' preferences.	1	2	3	4	5
	20 My teammates like to do various team tasks.	1	2	3	4	5
	21 My teammates enjoy thinking.	1	2	3	4	5
	22 I have a good knowledge about my teammates' tendencies.	1	2	3	4	5
	23 My teammates are committed to the team goal.	1	2	3	4	5
	24 My teammates encourage each other's work in order to improve various team task outcomes.	1	2	3	4	5
	25 My teammate strives to express his or her opinion.	1	2	3	4	5

APPENDIX F. TASK-SMM STRUCTURE: PHASE I

SSN (Last 4 digits): _____ Team #: _____

Below are several characteristics associated with the interactions that typically occur between team members. Please rate how related each of these characteristics is to each of the other characteristics in completing the team project.

Directions: In the upper left-hand square you are asked to indicate how similar ‘familiarization with product function and properties’ is to ‘Describe product function’. Based on your experience with the **Phase I task**, determine how related these two terms are. Using the following scale, please complete all the boxes below.

-4	-3	-2	-1	0	1	2	3	4
Negatively Related: A high degree of one requires a low degree of the other. Having a lot of one means you must have very little of the other				Totally unrelated				Positively Related: A high degree of one requires a high degree of the other. Having a lot of one means you must have a lot of other as well

	Describe Product function	Determine Required product properties	Analyze Product components	Measure Components	Convert component data into Mechanical drawing
Familiarization with Product function and properties					
	Describe Product function				
		Determine Required product properties			
			Analyze Product components		
				Measure Components	

APPENDIX G. TASK-SMM STRUCTURE: PHASE II

SSN (Last 4 digits): _____ Team #: _____

Below are several characteristics associated with the interactions that typically occur between team members. Please rate how related each of these characteristics is to each of the other characteristics in completing the team project.

Directions: In the upper left-hand square you are asked to indicate how similar ‘Determine product manufacturing’ is to ‘Determine materials composition for each of the components.’ Based on your experience with the **Phase II task**, determine how related these two terms are. Using the following scale, please complete all the boxes below.

-4	-3	-2	-1	0	1	2	3	4
Negatively Related: A high degree of one requires a low degree of the other. Having a lot of one means you must have very little of the other				Totally unrelated				Positively Related: A high degree of one requires a high degree of the other. Having a lot of one means you must have a lot of other as well

	Determine materials Composition for Each of the components	Determine manufacturing Processes used to create Individual piece	Determine Assembly challenges	Test product functionality and Performance	Perform durability tests and Determine product life cycle	Determine tooling Techniques used	Figure out how the components were assembled into the product	Test various functions and Features of the product
Determine product Manufacturing								
Determine materials Composition for Each of the components								
Determine manufacturing process used to create individual piece								
Determine Assembly challenges								
Test product functionality and Performance								
Perform durability tests and Determine product life cycle								
Determine tooling Techniques used								
Figure out how the components were assembled into the product								

APPENDIX H. TASK-SMM STRUCTURE: PHASE III

SSN (Last 4 digits): _____ Team #: _____

Below are several characteristics associated with the interactions that typically occur between team members. Please rate how related each of these characteristics is to each of the other characteristics in completing the team project.

Directions: In the upper left-hand square you are asked to indicate how similar ‘Identify points of improvement’ is to ‘Identify problems/issues.’ Based on your experience with the **Phase III task**, determine how related these two terms are. Using the following scale, please complete all the boxes below.

-4	-3	-2	-1	0	1	2	3	4
Negatively Related: A high degree of one requires a low degree of the other. Having a lot of one means you must have very little of the other				Totally unrelated				Positively Related: A high degree of one requires a high degree of the other. Having a lot of one means you must have a lot of other as well

	Performing analysis on Product criteria	Identify potential Solutions	Determine product optimization Solution details	Assess overall Product	Validate /justify product Optimization solution details	Identify problems/Issues	Identify solution Details	Modify solution details until Reached desired state	Determine product goals
Identify points of Improvement									
Performing analysis on Product criteria									
Identify potential Solutions									
Determine product optimization Solution details									
Assess overall Product									
Validate/justify product Optimization solution details									
Identify problems/Issues									
Identify solution Details									
Modify solution details until Reached desired state									

APPENDIX I. TASK-SMM DEGREE: PRE-PHASE I

SSN (Last 4 digits): _____ Team #: _____

This questionnaire involves rating and describing how you perceive your team member as well as yourself based on your perceptions prior to working with your partner on the course project. Please rate the following statements by circling the number the best describes your level of agreement. (1=very low and 5=very high; 1=strongly disagree and 5= strongly agree)

Part I: Task-SMM						
Statements		Very Low	Low	Medium	High	Very High
Task knowledge	1 What is your team’s level for describing product function?	1	2	3	4	5
	2 What is your team’s level for determining required product properties?	1	2	3	4	5
	3 What is your team’s level for measuring components in terms of types and dimensions and quantity?	1	2	3	4	5
	4 What is your team’s level for converting component data into mechanical drawing?	1	2	3	4	5
Statements		Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree
Team environment	5 There is an atmosphere of trust among my teammate.	1	2	3	4	5
	6 My team creates a work environment that promotes productive results.	1	2	3	4	5
	7 My team creates a safe environment to openly discuss any issue related to the team’s success.	1	2	3	4	5
	8 My team acknowledges and rewards behaviors that contribute to an open team climate.	1	2	3	4	5
	9 My team often utilizes different opinions for the sake of obtaining optimal outcomes.	1	2	3	4	5
	10 Discussions for decision-making occur within my team during meetings so that team meetings are viewed as useful activities.	1	2	3	4	5
	11 My team has a positive team climate.	1	2	3	4	5
	12 My team has the right experience so that a critical mass of experienced people is available to the team.	1	2	3	4	5
	13 My team knows the environmental constraints when we perform various team tasks.	1	2	3	4	5

APPENDIX J. TASK-SMM DEGREE: BETWEEN PHASE I AND PHASE II

SSN (Last 4 digits): _____ Team #: _____

This questionnaire involves rating and describing how you perceive your team members as well as yourself during the process of your team project. Please rate the following statements by circling the number the best describes your level of agreement. (1=strongly disagree and 5= strongly agree)

Part I: Task-SMM						
Statements		Very Low	Low	Medium	High	Very High
Task knowledge	1 What is your team’s level for describing product function?	1	2	3	4	5
	2 What is your team’s level for determining required product properties?	1	2	3	4	5
	3 What is your team’s level for measuring components in terms of types and dimensions and quantity?	1	2	3	4	5
	4 What is your team’s level for converting component data into mechanical drawing?	1	2	3	4	5
	5 What is your team’s level for determining materials composition for each of the components?	1	2	3	4	5
	6 What is your team’s level for determining manufacturing processes used to create each individual piece?	1	2	3	4	5
	7 What is your team’s level for determining tooling techniques used?	1	2	3	4	5
	8 What is your team’s level for testing various functions and features of the product?	1	2	3	4	5
	9 What is your team’s level for performing durability tests and determining product life cycle?	1	2	3	4	5
	10 What is your team’s level for figuring out how the components were assembled into the product?	1	2	3	4	5
Statements		Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree
Team environment	11 There is an atmosphere of trust among my teammates.	1	2	3	4	5
	12 My team creates a work environment that promotes productive results.	1	2	3	4	5
	13 My team creates a safe environment to openly discuss any issue related to the team’s success.	1	2	3	4	5
	14 My team acknowledges and rewards behaviors that contribute to an open team climate.	1	2	3	4	5
	15 My team often utilizes different opinions for the sake of obtaining optimal outcomes.	1	2	3	4	5
	16 Discussions for decision-making occur within my team during meetings so that team meetings are viewed as useful activities.	1	2	3	4	5
	17 My team has a positive team climate.	1	2	3	4	5
	18 My team has the right experience so that a critical mass of experienced people is available to the team.	1	2	3	4	5
	19 My team knows the environmental constraints when we perform various team tasks.	1	2	3	4	5

APPENDIX K. TASK-SMM DEGREE: BETWEEN PHASE II AND PHASE III

SSN (Last 4 digits): _____ Team #: _____

This questionnaire involves rating and describing how you perceive your team members as well as yourself during the process of your team project. Please rate the following statements by circling the number the best describes your level of agreement. (1=strongly disagree and 5= strongly agree)

Part I: Task-SMM							
Statements		Very Low	Low	Medium	High	Very High	
Task knowledge	1	What is your team's level for determining materials composition for each of the components?	1	2	3	4	5
	2	What is your team's level for determining manufacturing processes used to create each individual piece?	1	2	3	4	5
	3	What is your team's level for determining tooling techniques?	1	2	3	4	5
	4	What is your team's level for testing various functions and features of the product?	1	2	3	4	5
	5	What is your team's level for performing durability tests and determining product life cycle?	1	2	3	4	5
	6	What is your team's level for figuring out how the components were assembled into the product?	1	2	3	4	5
	7	What is your team's level for identifying problems/issues?	1	2	3	4	5
	8	What is your team's level for identifying potential solutions?	1	2	3	4	5
	9	What is your team's level for determining product goals?	1	2	3	4	5
	10	What is your team's level for identifying solution details?	1	2	3	4	5
	11	What is your team's level for performing analysis on product criteria?	1	2	3	4	5
	12	What is your team's level for assessing overall product improvement?	1	2	3	4	5
	13	What is your team's level for modifying solution details until the desired state is reached?	1	2	3	4	5
Statements		Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree	
Team environment	14	There is an atmosphere of trust among my teammates.	1	2	3	4	5
	15	My team creates a work environment that promotes productive results.	1	2	3	4	5
	16	My team creates a safe environment to openly discuss any issue related to the team's success.	1	2	3	4	5
	17	My team acknowledges and rewards behaviors that contribute to an open team climate.	1	2	3	4	5
	18	My team often utilizes different opinions for the sake of obtaining optimal outcomes.	1	2	3	4	5
	19	Discussions for decision-making occur within my team during meetings so that team meetings are viewed as useful activities.	1	2	3	4	5
	20	My team has a positive team climate.	1	2	3	4	5
	21	My team has the right experience so that a critical mass of experienced people is available to the team.	1	2	3	4	5
	22	My team knows the environmental constraints when we perform various team tasks.	1	2	3	4	5

APPENDIX L. TASK-SMM DEGREE: POST-PHASE III

SSN (Last 4 digits): _____ Team #: _____

This questionnaire involves rating and describing how you perceive your team members as well as yourself during the process of your team project. Please rate the following statements by circling the number the best describes your level of agreement. (1=strongly disagree and 5= strongly agree)

Part I: Task-SMM						
Statements		Very Low	Low	Medium	High	Very High
Task Knowledge	1 What is your team's level for identifying problems/issues?	1	2	3	4	5
	2 What is your team's level for identifying potential solutions?	1	2	3	4	5
	3 What is your team's level for determining product goals?	1	2	3	4	5
	4 What is your team's level for identifying solution details?	1	2	3	4	5
	5 What is your team's level for performing analysis on product criteria?	1	2	3	4	5
	6 What is your team's level for assessing overall product improvement?	1	2	3	4	5
	7 What is your team's level for modifying solution details until the desired state is reached?	1	2	3	4	5
Statements		Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree
Team Environment	8 There is an atmosphere of trust among my teammate.	1	2	3	4	5
	9 My team creates a work environment that promotes productive results.	1	2	3	4	5
	10 My team creates a safe environment to openly discuss any issue related to the team's success.	1	2	3	4	5
	11 My team acknowledges and rewards behaviors that contribute to an open team climate.	1	2	3	4	5
	12 My team often utilizes different opinions for the sake of obtaining optimal outcomes.	1	2	3	4	5
	13 Discussions for decision-making occur within my team during meetings so that team meetings are viewed as useful activities.	1	2	3	4	5
	14 My team has a positive team climate.	1	2	3	4	5
	15 My team has the right experience so that a critical mass of experienced people is available to the team.	1	2	3	4	5
	16 My team knows the environmental constraints when we perform various team tasks.	1	2	3	4	5

APPENDIX M. TEAM PERFORMANCE MEASURES

Phase I

	Very Low				Very High
1. Describe product function	1	2	3	4	5
2. Determine required product properties (mechanical, physical, etc.)	1	2	3	4	5
3. Understand working principle	1	2	3	4	5
4. Analyze product components	1	2	3	4	5
5. Convert component data into mechanical drawing	1	2	3	4	5

Phase II

	Very Low				Very High
1. Determine materials composition for each component	1	2	3	4	5
2. Determine manufacturing processes used to create each component	1	2	3	4	5
3. Determine tooling techniques used	1	2	3	4	5
4. Determine assembly scheme	1	2	3	4	5
5. Identify designs intended for DFA, DFD, and automation	1	2	3	4	5

Phase III

	Very Low				Very High
1. Test product functionalities	1	2	3	4	5
2. Test product durability	1	2	3	4	5
3. Identify design/manufacturing problems and issues	1	2	3	4	5
4. Propose design alternatives	1	2	3	4	5
5. Validate and justify proposed design alternatives	1	2	3	4	5

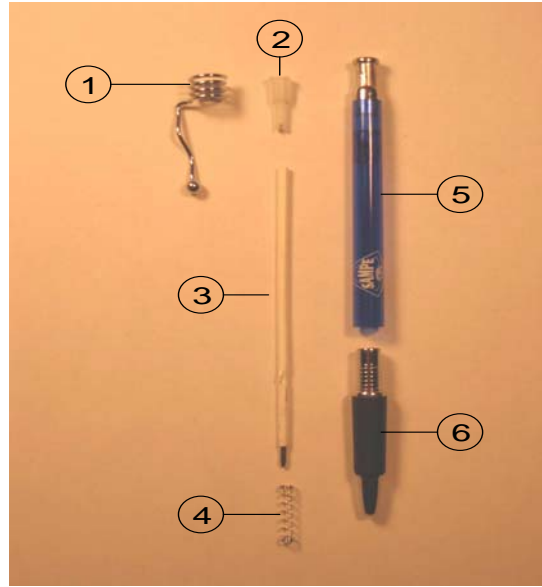
APPENDIX N. INDIVIDUAL PERFORMANCE MEASURES: PHASE I

SSN (Last 4 digits): _____ Team #: _____

Based on the following photos, please respond to each questions below. Your sincere and honest answers are expected answering the questions.

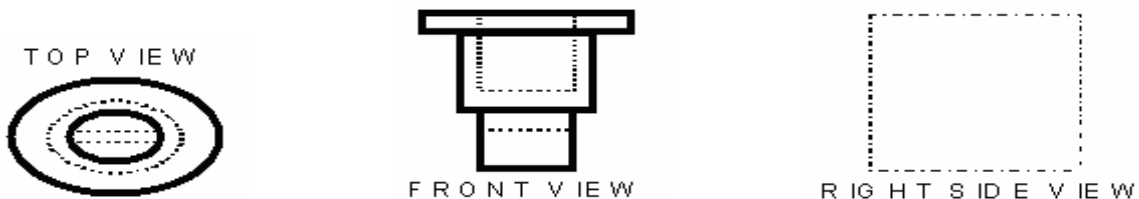


(a) Assembled product



(b) Disassembled product

1. Describe the intended function(s) of the product in Figure (a).
2. List significant properties of the product (Figure a) in order to perform the intended function(s).
3. Explain the function of Part 4 (Figure b).
4. Given the top view and front view of the product, please complete the right-side view in the following mechanical drawing for Part 6?



5. What type of fit (e.g. snug, shrink, etc.) is required between Parts 1 and 5 (Figure b)?

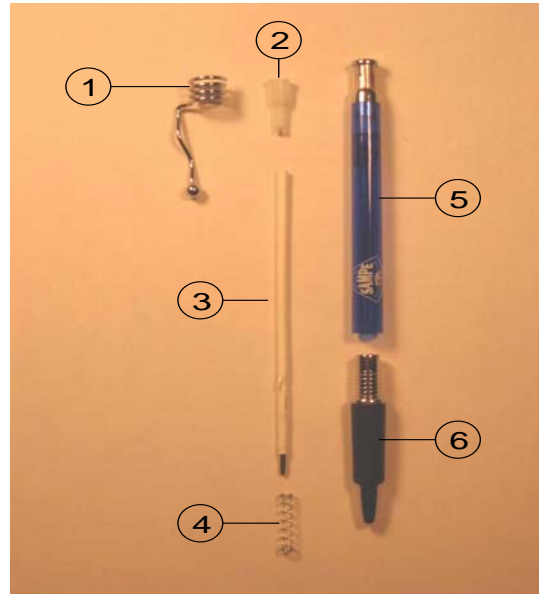
APPENDIX O. INDIVIDUAL PERFORMANCE MEASURES: PHASE II

SSN (Last 4 digits): _____ Team #: _____

Based on the following photos, please respond to each questions below. Your sincere and honest answers are expected answering the questions.



(a) Assembled product



(b) Disassembled product

1. Part 3 (Figure b) is subjected to constant compression in operation. Determine the critical mechanical properties required for this part.
2. Part 6 (Figure b) is a composite and consists of two different materials – aluminum and rubber. Explain the purpose of using this composite.
3. Describe the step-by-step manufacturing processes for Part 4 (Figure b).
4. Estimate what type of material Part 2 is made from (Figure b).
5. Describe the order of assembling Parts 1-6 (Figure b).

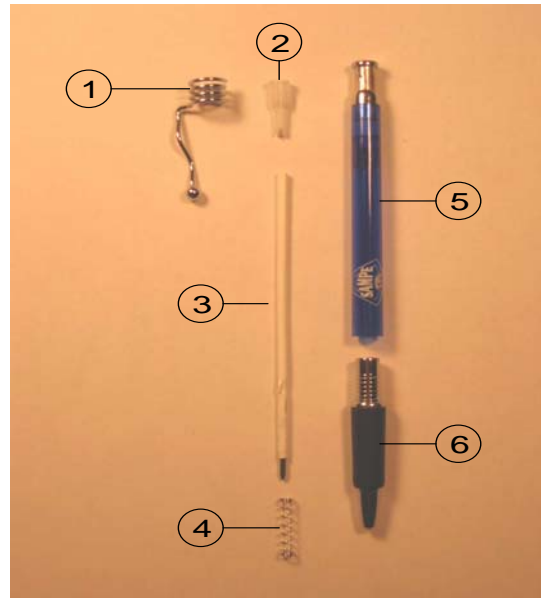
APPENDIX P. INDIVIDUAL PERFORMANCE MEASURES: PHASE III

SSN (Last 4 digits): _____ Team #: _____

Based on the following photos, please respond to each questions below. Your sincere and honest answers are expected answering the questions.



(a) Assembled product



(b) Disassembled product

1. If the assembly between Parts 5 and 6 were to be automated, which one of the following location methods would be necessary? (1) plane; (2) concentric; (3) radial
2. Which part do you think has the highest **material** cost? Which part do you think has the highest **manufacturing** cost?
3. A design alternative was proposed, such that Parts 1 and 5 are one unit, made up of the same material as Part 5. What are the advantages and disadvantages of this design?
4. What type of test would you perform to assess the durability of the product under service conditions?
5. Suppose a frequent problem was reported, in which the internal threads in Part 5 (that mate with the external threads in Part 6) wear out prematurely. What design modification would you propose to correct this durability problem?

APPENDIX Q. HUMAN SUBJECT APPROVAL MEMORANDUM AND INFORMED
CONSENT FORM



Office of the Vice President For Research
Human Subjects Committee
Tallahassee, Florida 32306-2742
(850) 644-8633 FAX (850) 644-4392

REAPPROVAL MEMORANDUM

Date: 2/23/2007

To:
Miyoung Lee
MC 2735

Dept.: **EDUCATIONAL PSYCHOLOGY AND LEARNING SYSTEMS**

From: **Thomas L. Jacobson, Chair**

A handwritten signature in black ink, appearing to read "Thomas L. Jacobson".

Re: **Reapproval of Use of Human subjects in Research:**
An investigation of the relationships between shared mental models and team performance

Your request to continue the research project listed above involving human subjects has been approved by the Human Subjects Committee. If your project has not been completed by 2/21/2008 please request renewed approval.

You are reminded that a change in protocol in this project must be approved by resubmission of the project to the Committee for approval. Also, the principal investigator must report to the Chair promptly, and in writing, any unanticipated problems involving risks to subjects or others.

By copy of this memorandum, the Chairman of your department and/or your major professor are reminded of their responsibility for being informed concerning research projects involving human subjects in their department. They are advised to review the protocols of such investigations as often as necessary to insure that the project is being conducted in compliance with our institution and with DHHS regulations.

Cc: Tristan Johnson
HSC No. 2007.126-R

PARTICIPANT CONSENT FORM

An Investigation of the Relationships between Shared Mental Models and Performances

Principal Investigator: Miyoung Lee
Learning Systems Institute, Florida State University

Faculty Supervisor: Dr. Tristan Johnson
Learning Systems Institute, Florida State University

I freely and voluntarily consent to be a participant in the study entitled "An Investigation of the relationships between shared mental models and Performances" This project is being conducted by Miyoung, Doctoral Candidate, Florida State University, and supervised by Tristan Johnson, Ph.D., of the Learning Systems Institute at Florida State University. I understand the purpose of her study is to examine how the shared mental model will change over time and identify how the change will occur in terms of the task and team-related models.

I understand that if I participate in the study I will be asked to reflect on my understanding of my team project on a complex problem.

I understand I will be asked to fill out a demographic survey and answer questionnaires during various stages of the class depicting team project on a complex problem. The total time commitment for the demographic survey will be about 10 minutes and the total time commitment will be approximately 180 minutes for the other questionnaires.

I understand my participation is voluntary and I may stop participation at anytime. If I decide to stop participation, I will not be penalized for withdrawing my participation. All my responses to the demographic survey and questionnaires will be kept confidential and identified by a coding system. My name will not appear on any of the results. No individual responses will be reported. Only team findings will be reported.

I understand there is a possibility of a minimal level of risk involved if I agree to participate in this study. I understand that the unlikely event of accidental identification carries the potential of embarrassment.

I understand there are benefits for participating in this study. First, my own awareness about solving complex problems may be increased. In addition, I will be providing valuable insight into the change of task-related mental model and team-related mental model between team members regarding the team task.

I understand that this consent may be withdrawn at any time without prejudice, penalty or loss of benefits to which I am otherwise entitled. I have been given the right to ask and have answered any inquiry concerning the study. Questions, if any, have been answered to my satisfaction.

I understand that I may contact Miyoung Lee, Learning Systems Institute, Florida State University at (850) 459-4863 or via email at myl03@fsu.edu, for answers to questions about this study or my rights. Team results will be sent to me upon my request.

I HAVE HAD THE OPPORTUNITY TO READ THIS CONSENT FORM AND ASK QUESTIONS ABOUT THE STUDY. I AM PREPARED TO PARTICIPATE IN THIS ENTITLED "An Investigation of the relationships between shared mental model and team performance"

Participant's Name (Please print)

Participant's Signature

Principle Investigator's Signature

Date

Date



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BIOGRAPHICAL SKETCH

EDUCATION

- Florida State University, Tallahassee, Florida
Ph.D. in Instructional Systems, 2007
Dissertation: Understanding Changes in Team-Related and Task-Related Mental Models and Their Effects on Team and Individual Performance
Fields of interest: Team Performance, Shared Mental Model, Expertise, Collaborative Problem Solving, and Alternative Web-Based Learning Environment Design

- Hanyang University, Seoul, Korea
M.A., Educational Technology, 2003
Thesis: The Effects of the Collaborative Representation Supporting Tool on Problem Solving Processes and Outcomes in Web-Based Collaborative PBL Environments

- Sookmyung Women's University, Seoul, Korea
B.A., Major 1: Education, 2001
Major 2: English Language & Literature, 2001

CERTIFICATES

Certificate of Online Instructional Development awarded by Department of Educational Psychology & Learning Systems
Certificate of Mentors to Support Online Students awarded by ODDL (The Office for Distributed and Distance Learning)
Certificate of Teacher in English for Secondary Education awarded by Minister of Education, Seoul, Korea.

EMPLOYMENT/WORK EXPERIENCE

Instructional Systems, Florida State University

Tallahassee, Florida

Instructor, 8/2005-4/2007

EME2040 Introduction to Educational Technology -Taught pre-service teachers

Learning Systems Institute, Florida State University

Tallahassee, Florida

Research Assistant, 8/2005-12/2006,

Studied on Shared Mental Model and Team Performance

Office for Distributed & Distance Learning (ODDL), Florida State University

Tallahassee, Florida

Web-Based Course Designer 4/2005-8/2005

Developed online team-based learning curriculums for distance students in Information studies

Learning Systems Institute (RITL), Florida State University

Tallahassee, Florida

Research Assistant, 1/2005- 8/2005

Participated in Gesture Team Project, Study on Pedagogical Agent

Learning Systems Institute, Florida State University

Tallahassee, Florida

Research Assistant, 1/2004-12/2004

Participated in PQS and E-plan projects

Instructional Systems, Florida State University

Tallahassee, Florida

Teaching Assistant, 8/2003-12/2003

EME 5457: Introduction to Distance Learning

JOURNAL PUBLICATIONS

- Johnson, T.E., Lee, Y., **Lee, M.**, O'Connor, D., Khalil, M.K, & Huang, X. (2007). Measuring Sharedness of Team-related Knowledge: Design and Validation of a Shared Mental Model Instrument, *Human Resource Development International*,10(4)
- Lee, M.** & Baylor, A. (2006). Designing Metacognitive Maps for Web-Based Learning. *Journal of Educational Technology & Society*. vol 9(1)
- Park, S., Kim, M., Lee, Y., Son, C., **Lee, M** (2005).The Effects of Visual Illustrations on Learners' Achievement and Interest in PDA- (Personal Digital Assistant) Based Learning. *Journal of Educational Computing Research*,33(2)
- Lee, M.** & Kim, D. (2005). The Effects of the Collaborative Representation Supporting Tool on Problem Solving Processes and Outcomes in Web-Based Collaborative PBL Environments. *Journal of Interactive Learning Research*, 16(3)

PROCEEDINGS

- Baylor, A. L., Kim, S., Son, C. & **Lee, M.** (2005) Designing effective nonverbal communication for pedagogical agents. Proceedings of AI-ED (Artificial Intelligence in Education), Amsterdam.
- Lee, M.** & Lee, Y. (2004). How to Measure Team Communication in Web-based Collaborative Learning: The Application of SNA (Social Network Analysis). Proceeding of World Conference on E-Learning in Corporate, Government, Healthcare, & Higher Education 2004. Washington, WA
- Lee, M.** & Lee, Y. (2004). Implementing a Web-based Visualization Tool for Collaborative Problem Representation. Proceeding of World Conference on E-Learning in

Corporate, Government, Healthcare, & Higher Education 2004. Washington, WA.

Lee, Y. & **Lee, M.** (2004). Promoting Learners' Problem Solving Performance through a Cognitive Tool for Mapping Knowledge. Proceeding of World Conference on E-Learning in Corporate, Government, Healthcare, & Higher Education 2004. Washington, WA.

Kim, M., **Lee, M.** & Park, S. (2004) Potential Areas in Calculating Return On Investment for E-learning: An investigation through case studies, Proceeding of World Conference on E-Learning in Corporate, Government, Healthcare, & Higher Education (E-LEARN 2004), Washington, D.C

Lee, M., Park, S. & Kim, M. (2004, Nov) Finding Return On Investment Factors in E-Learning, Proceeding of E-Learn 2004 World Conference of Association for the Advancement of Computing in Education (AACE), Washington, D.C.

Lee, M., Johnson, T., Khalil, M., O'Conner, D. & Huang, S. (2004). Understanding Instructional Design Team: A Study of the Change in Shared mental Model, Annual Meeting of American Educational Communication and Technology 2004, Chicago.

Lee, M., Lee, Y., & Warren, R. (Mar 2004). Mapping the Metacognition in Web Based Instruction. Proceeding of International Conference on Society for Information Technology and Teacher Education. Atlanta, Georgia.

PRESENTATIONS

Lee, M. & Johnson, T. (2006, April). Uncovering Shared Mental Model in an Ethnography Approach. Presented at the Annual meeting of the American Educational Research Association (AERA), San Francisco, California.

Son, C., Lee, Y., **Lee, M.** , Park, S., & Kim, M.(2006, April). The Effects of Hypertext Structure in Handheld Computers on Learning and Attitudes. Presented at the Annual meeting of the American Educational Research Association (AERA), San Francisco, California.

Reiser, R., Sievert, J., Huang, X., Warren, D., Kim, H., & **Lee, M** (2006, April), Student Perceptions of the Challenges/Benefits of the Practicum. The Annual meeting of the American Educational Research Association (AERA), San Francisco, California.

Baylor, A.L., Kim, Son, C. & **Lee, M** (2006, April) Effective Pedagogical Agent Nonverbal Communication for Different Learning Outcomes. The Annual meeting of the American Educational Research Association (AERA), San Francisco, California.

- Lee, M.**, & Jeong, A. (2005). The Effects of the Quality of Message Content on Interaction Patterns and Level of Critical Discourse in Online Discussion, Annual Meeting of the Association for Educational Communications and Technology 2005, Orlando.
- Lee, M.**, Johnson, T.E., O'Connor, D., & Khalil, M.K, Lee, Y. & Huang, S. (2005). The Effects of a Shared Mental Model on Team Performance, International Conference of the Association for Educational Communications and Technology (AECT), Orlando.
- Lee, M.**, & Flower, P. (2005). Using HPT methodology to solve performance problems in a non-profit organization, International Conference of the Association for Educational Communications and Technology (AECT), Orlando.
- Kim, M., **Lee, M.**, Lee, Y., Park, S., Ryu, J., and Son, C. (2005). Potential Use of PDAs (Personal Digital Assistant) in Education: A Result of Survey, International Conference of the Association for Educational Communications and Technology (AECT), Orlando, Florida.
- Park, S., Kim, M., Lee, Y., **Lee, M.**, and Son, C. (2005). The Effects of Visual Illustration on Learning Interest and Achievement in PDA (Personal Digital Assistant) based Learning, International Conference of the Association for Educational Communications and Technology (AECT), Orlando, Florida.
- Huang, S., Johnson, T.E., Khalil, M.K., O'Connor, D., & **Lee, M.** (2005) The Role of Self-Efficacy in Online Learning: What Do We Know and What Can We Do? , International Conference of the Association for Educational Communications and Technology (AECT), Orlando, Florida.
- Johnson, T.E., O'Connor, D., **Lee, M.** & Khalil, M.K (2005). Measuring Team Shared Knowledge Using Analysis-Constructed Shared Mental Models Methods: Using Concept Maps for the Measurement of Shared Understanding in Teams, EARLI conference
- Kim, M., **Lee, M.**, Lee, Y., Park, S., & Son, C. (2005). Overview of Return On Investment (ROI) in E-Learning, SEA conference.
- Johnson, T.E., Huang, S., Lee, Y., O'Connor, D., Khalil, M.K., **Lee, M.**, & Brown, L. (2005). Pilot Testing of a Collective Efficacy Instrument, SEA conference.
- Johnson, T.E., Huang, S., Lee, Y., O'Connor, D., Khalil, M.K., **Lee, M.**, & Brown, L. (2005). Improving Team Performance: the Role of Team Efficacy, SEA conference
- Lee, M.**, Park, S., & Kim, M. (2004) Finding Return On Investment Factors in E-Learning. E-Learn conference, Washington, DC, USA, November 1-5, 2004.

- Lee, M.**, & Lee Y. (2004). Implementing a Web-based Visualization Tool for Collaborative Problem Representation, E-Learn conference, Washington, DC, USA, November 1-5, 2004.
- Lee, M.** & Lee Y. (2004). How Can We Measure Team Performance? : The Application of Social Network Analysis. International Conference of the Association for Educational Communications and Technology (AECT), Chicago.
- Lee, M.**, Lee Y., Johnson, T. & Huang, X. (2004). The Conceptual Framework of Factors Affecting Team Shared Mental Model. International Conference of the Association for Educational Communications and Technology (AECT), Chicago.
- Lee, M.**, Johnson, T., Khalil, M., O'Connor, D. & Huang, S. (2004). Understanding Instructional Design Team: A Study of the Change in Shared mental Model, International Conference of the Association for Educational Communications and Technology (AECT), Chicago.
- Huang, S., Johnson, T., Khalil, M., O'Connor, D. & **Lee, M.** (2004). Understanding Instructional Design Team: The Development and Validation of Collective Efficacy Instrument. International Conference of the Association for Educational Communications and Technology (AECT), Chicago.
- Lee, Y., **Lee, M.** & Kim, M. (2004). The Factors Affecting Successful Problem Solving Performance: The Review of Literature. International Conference of the Association for Educational Communications and Technology (AECT), Chicago.
- O'Connor, D., Johnson, T.E. Khalil, M.K., **Lee, M.**, & Huang, S. (2004). 'Team Cognition: Shared Mental Models In Performance Improvement Teams' International Conference of the Association for Educational Communications and Technology (AECT), Chicago.
- Lee, M.**, & Kim, D. (2004). Developing the Collaborative Representation Supporting Tool (CRST) in Web-Based Collaborative PBL Environments. SITE 2004- Society for Information Technology & Teacher Education International Conference.
- Lee, M.**, Lee, Y. & Warren, D. (2004). Mapping the Metacognition in Web Based Learning Environment . SITE 2004--Society for Information Technology & Teacher Education International Conference.
- Johnson, T.E. , Khalil, M.K., O'Connor, D., Huang, S., Brown, L., **Lee, M.**, Lee, Y., Kim, D. Razzouk R. (2004). Evaluating Team Cognition, SEA conference.
- Lee, Y., Kim, S., **Lee, M.** (2003). Evaluating the Computerized Tools for conducting a Cognitive Task Analysis. International Conference of the Association for Educational Communications and Technology (AECT), Anaheim, CA.

SERVICE

SERVICE TO PROFESSIONS

- Volunteer for 2005 AECT in Orlando, FL
- Proposal Reviewer for 2004 AERA in Montreal, Canada
- Volunteer for 2004 SITE in Atlanta, Georgia
- Volunteer for 2003 AECT in Anaheim, CA
- Facilitator for 2003 AECT in Anaheim, CA

COMMUNITY SERVICE

Instructional Systems Student Association, Vice-President of Operations/Finance (Fall 2004-Fall 2006)

Responsible for assisting the President, Maintain FSU-ISSA organizational structure and integrity. Responsible for handling, accounting, & preparation of budget reports for all collected/existing monetary funds. Responsible for the general organizational operations (planning organizational meetings, maintenance of the FSU-ISSA Constitution, compliance with FSU policies and addressing/presenting doctoral student issues to the other student officers).