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# UNDERSTANDING TEAM COGNITION IN PERFORMANCE IMPROVEMENT TEAMS: A META-ANALYSIS OF CHANGE IN SHARED MENTAL MODELS

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**Abstract**. Team cognition is comprised of several factors including shared knowledge or shared mental models (SMM). As there is little agreement about best methods for measuring SMM, this study utilized data from four previous studies and the ACSMM methodology for analysis of data. Findings about SMM in Performance Improvement teams indicate that changes in SMM take place during team task performance and that the changes are similar from one PI team to another.

## 1 Background

Difficult, complex, or ill-structured problems and tasks are not easily addressed by a single individual. As these situations are prevalent in society, we often see teams created to address these issues (Stout, Cannon-Bowers, Salas, & Milanovich, 1999). The benefit of using teams is that the team members contribute to team performance through individual knowledge, background, skills and particular roles/responsibilities. Performance improvement (PI) teams may possess knowledge related to their individual role and responsibilities (e.g., subject matter experts, programmers, and instructional designers), and share an understanding about the overall process of performing the task. Although not all members completely share identical knowledge, successful team performance requires a level of shared knowledge about the task (McIntyre & Salas, 1995).

Team shared knowledge (team cognition) includes knowledge about team members, task-specific information, and team processes (Fiore & Salas, 2004). In order to understand team cognition, these factors are often represented as a shared mental model (SMM). Mental models, like schemata, are believed to reflect an individual's knowledge structure (Ericsson & Simon, 1984, 1993; Newell, & Simon, 1972; Senge, 1990). It is believed that mental models can be shared across individuals as in a group or team (Mathieu, et al., 2000). Shared mental models are most often described in terms of their elements and their interrelationships, focusing on differences (Banks & Millward, 2000) or on commonalities (Blickensderfer, Cannon-Bowers, & Salas, 1997; Stoyanova & Kommers, 2002).

Research also indicates that changes in team shared mental models (SMM) take place as teams work toward completion of their goal (O'Connor, 2004). However, this indication was based on PI teams performing a single task. In order to better understand and substantiate previous research findings regarding the change of SMM over time, we seek to study several PI teams conducting different tasks.

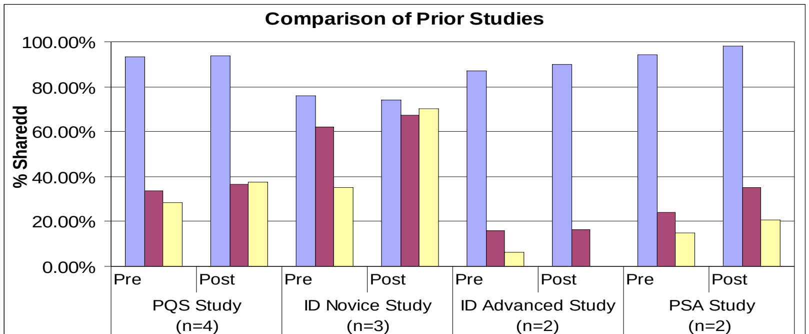
## 2 Meta-Analysis of Prior Studies

The purpose of this meta-analysis was to gain an understanding about the similarities and differences of SMM change in different PI teams as presented in four pervious studies. Specifically, we are looking for change characteristics of SMM that are common to all PI teams. The key question looked at the similarities between the shared mental models of task-related information between PI teams working in different contexts on different tasks?

The meta-analysis was comprised of four studies where newly formed PI teams worked in applied settings to conduct cognitively complex tasks. All teams created concept maps about the process of their specific task: Personnel Qualification Standards (PQS) teams (N=4) focused on the PQS revision, Instructional Design (ID Novice (N=4) and ID Advanced (N=2)) teams focused on formative evaluation and Performance Systems Analysis (PSA) teams (N=2) focused on performance systems analysis.

## 3 Method and Results

This meta-analysis involved a comparison of the results from four prior studies that utilized the ACSMM methodology (O'Connor & Johnson, 2004). The comparison involves taking each ACSMM for the teams in the study and calculating an average of shared concepts (nodes), links (node-connector-node combinations), and clusters (three or more concepts containing two or more connectors—cross links and hierarchical structure (Novak & Gowin, 1984)). This is done for both pre-task and post-task. These results are presented below (Figure 1).




| | PQS Study (n=4) Pre | PQS Study (n=4) Post | ID Novice Study (n=3) Pre | ID Novice Study (n=3) Post | ID Advanced Study (n=2) Pre | ID Advanced Study (n=2) Post | PSA Study (n=2) Pre | PSA Study (n=2) Post |
|---|---|---|---|---|---|---|---|---|
| Concepts | 93.37% | 93.86% | 75.81% | 74.19% | 87.05% | 89.83% | 94.00% | 98.00% |
| Links | 33.76% | 36.64% | 62.07% | 67.24% | 15.70% | 16.40% | 23.91% | 35.31% |
| Clusters | 28.46% | 37.36% | 35.00% | 70.00% | 6.25% | 0.00% | 14.77% | 20.50% |

**Figure 1.** Shared ACSMM elements from PI teams in prior studies (PQS, ID Novice, ID Advanced, PSA).

On visual inspection of the data presented in Figure 1, we see a general trend. In considering the average number shared concepts, three of the four studies showed an increase from pre-task to post-task. The ID Novice study showed a slight decrease. In considering the average number shared links and shared clusters, all four teams showed an increase in the number of shared links from pre-task to post-task. In considering the average number of shared clusters, three of the four teams showed an increase in the number of shared clusters from pre-task to post-task. The ID Advanced study showed a decrease in shared clusters from pre-task to post-task.

The greatest increase in percentage of shared concepts (+4.00%) was in the PSA study. The greatest increase in percentage of shared links (+11.4%) was also seen in the PSA study. The greatest increase in the percentage of shared clusters (+35.00%) was in the ID Novice study. Considering the average percent change of concepts, links, and clusters for each study, the greatest increase was 12.85% for the ID Novice study. The PSA study followed with 7.04% increase and then the PQS study showed an increase of 4.09%.The ID Advanced study showed a decrease of -0.92%.

## 4 Discussion

From the findings of this meta-analysis, there appears to be a change in SMM of PI teams. However, none of the studies calculated statistical significance on the change of percent sharedness of concepts, links, and clusters. While we do not yet have evidence to show that pre and post measures are significantly different, it is important to note that the elements shared at pre-task are not necessarily the same elements shared at post-task. For example, although there may be three shared concepts at pre-task (A, B, C), these may be the same or different from the three shared concepts at post-task (A, D, F). Consequently, there is a need to describe the qualitative changes.

From the qualitative assessment, there appear to be key patterns of change. These patterns of change include an increase in complexity of task-related knowledge as evidenced by change in shared concepts, links, and clusters from pre- to post-task. Second, SMMs become more organized from pre- to post-task. Indicators derived from this study suggest a need for continued investigation into a comprehensive understanding of team cognition in PI teams.

Generally, the post-task SMM presents a more accurate representation of the process and/or higher organization as measured by logic, structural organization, and spatial orientation. To illustrate, consider the following example pre and post ACSMM from representative teams of the ID Novice study and the ID Advanced study (Figure 2). The patterns of change in shared concepts are most visible in the unlinked concepts (to right of vertical line in ACSMM), clusters (shaded groupings), and structural organization of the links (placement of elements within the ACSMM).

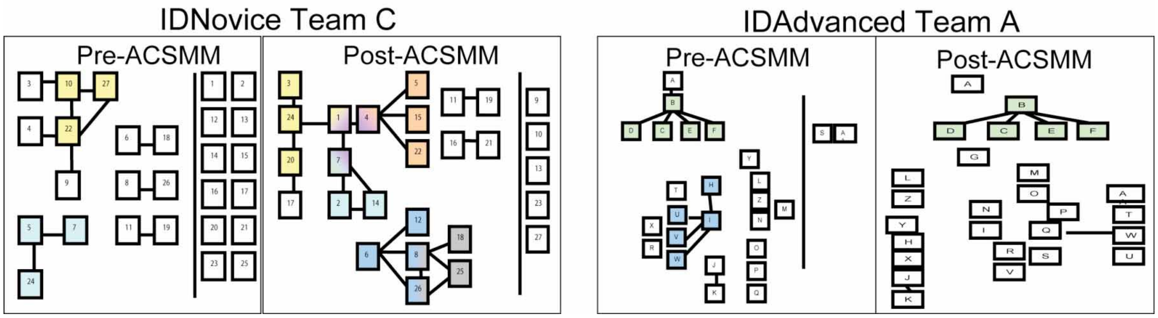



**Figure 2**. Examples of pre-task and post-task ACSMMs from representative teams of the ID Novice and ID Advanced studies.

The increase in linked concepts may indicate an increase in complexity of shared knowledge. For example, shared links may be placed in structurally different positions in the post-task ACSMM than in the pre-task ACSMM, thus representing qualitatively different shared knowledge. Clusters also tend to change from pre-task to post-task. Changes in shared clusters may indicate an increase in complexity of shared knowledge as measured by an increase in the number of clusters, an overlapping of clusters, or an increase in the size or detail of a given cluster. Any of the identified patterns of change may be include a change in knowledge accuracy.

Changes in clusters may also indicate a reorganization of shared knowledge or an increase in the detail of shared knowledge as represented by the placement of concepts and linking connectors within the clusters. For example, although the number of shared clusters decreased from pre to post in the ID Advanced example, there was actually an increase in shared knowledge. In the pre-task ACSMM, one of the two shared clusters was, although a possible logical relationship, an incorrect representation of the formative evaluation process. By eliminating this misconception in the post-task ACSMM, the ID Advanced team had fewer clusters and therefore less complexity of SMM, but also exhibited an increase in accuracy of shared knowledge over time.

Although the average number of shared concepts decreased for teams in the ID Novice study, the number of links and clusters increased, indicating an increase in complexity of shared knowledge from pre-task to post-task. Additionally, several overlapping clusters (identified by multiple shadings per concept) in the post-task ACSMM also indicate a qualitative change in complexity of SMM without necessarily changing the quantity of shared concepts or shared links.

In comparing across all PI teams involved in this meta-analysis, there is an indication that SMM in PI teams change similarly over time. However, it is unclear what factors may have influenced the change in team cognition as represented by the concept maps. Some external factors may include team leadership, context variables, shared team-related knowledge, demographics, time on task, skill level of team members, prior experience with team members and organizational incentives.

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