# Team Shared Cognitive Constructs: A Meta-Analysis Exploring the Effects of Shared Cognitive Constructs on Team Performance

*John R. Turner, Qi Chen, PhD, and Shelby Danks*

Sharing similar cognitive structures among team members is one key element for the collective to solve problems and work more efficiently (DeChurch & Mesmer-Magnus, 2010). Research has shown that team cognition is positively associated with team performance in both organizational and educational settings. Team shared cognition constructs are relatively new constructs and have been identified in the literature as team mental models, shared mental models, information sharing, transactive memory systems, cognitive congruence, and group learning. Cannon-Bowers and Salas (2001) called for better measures of shared cognition to be developed, partially through the integration of shared cognition measures across disciplines. The purpose of this meta-analysis is to look at these six team cognition constructs in an effort to help identify which measure, if any, results in predicting team performance best. Results indicated that information sharing was statistically significant compared to team mental memory and group learning, and marginally significant compared to transactive memory systems. Additionally, shared mental models and cognitive congruence showed higher associations with performance compared to team mental models, group learning, and transactive memory systems.

As the level of complexity and uncertainty increases, it is more likely that a single individual is going to make a bad decision (Surowiecki, 2005). In today's complex work environment, organizations are required to use teams to solve problems efficiently and effectively (DeChurch & Mesmer-Magnus, 2010). Akkerman et al. (2007) pointed out that group work is not only the cornerstone of organizational life, but that it is becoming more prevalent in educational settings. Leonard and Swap (1999) highlighted the benefits of using teams over a single individual: "Put enough *different* individual lenses together, and you have a kaleidoscope of ideas" (p. 21). For teams to operate effectively, DeChurch and Mesmer-Magnus (2010) identified team members' need to share similar cognitive structures. Cannon-Bowers and Salas (2001) identified three benefits to looking at shared cognition:

1. Shared cognition has potential value as an explanatory mechanism.
2. Shared cognition has the potential to be a valuable predictive variable in teams.
3. Shared cognition may help practitioners to diagnose a team's problems and provide insight into how to solve them. (p. 196)



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In their meta-analysis on cognitive underpinnings and effective teamwork, DeChurch and Mesmer-Magnus (2010) confirmed that team cognition is associated with team performance. They identified that team cognition added 7% explained variance in team performance, above and beyond the 12% explained variance in team performance from team cohesion and team behavioral processes combined. Primarily focused on team mental models (TMM) and transactive memory systems (TMS), DeChurch and Mesmer-Magnus did recognize other forms of team cognition: cognitive consensus, collective cognition, group cognition, shared cognition, and shared mental models (see DeChurch & Mesmer-Magnus, 2010, Table 1, for more alternative cognitive constructs).

In addition to the forms of team cognition identified by DeChurch and Mesmer-Magnus (2010), Mohammed and Dumville (2001) noted other forms of team cognition. For example, team mental models have been studied primarily by industrial and organizational psychologists, information sharing has been studied by social psychologists, transactive memory systems have been studied by cognitive psychologists, group learning has been studied in decision making, and cognitive consensus has been studied by organizational behaviorists (Mohammed & Dumville, 2001). Additional forms of shared cognition have been identified by Mohammed, Ferzandi, and Hamilton (2010): team mental models, team situation awareness, transactive memory, group learning, and strategic consensus.

Researchers have used different cognitive constructs interchangeably, leading to identifying or measuring the wrong cognitive construct (DeChurch & Mesmer-Magnus, 2010). These problems and others have led to this comment by Cannon-Bowers and Salas (2001): "Better measures of shared cognition are needed" (p. 200). Cannon-Bowers and Salas (2001) recommended that researchers define more specifically which type of outcome is being studied to provide better clarity to the research of shared cognition. Akkerman et al. (2007) highlighted that the literature is not consistent in labeling or defining shared cognition constructs.

The current study concentrates more specifically on comparing differing types of team cognition constructs rather than focusing on any one specific type of outcome. Attempts have been made to define the different types of team cognition constructs as well as identify how each has been measured as an attempt to provide better clarity for the literature. This meta-analysis provides a step toward answering Akkerman et al.'s (2007) request for "conceptual clarity of the core concepts and the methodology used" (p. 56) for studies relating to shared cognition. In addition, numerous performance outcomes have been pooled together for this meta-analysis with the intent of gaining a better perspective on which team cognitive constructs provide maximal benefits to teams and small groups. These outcomes have been identified along with how they have been measured in the literature to meet Cannon-Bowers and Salas's (2001) recommendation.

One attempt to gain better measures of team cognition is to integrate measures across disciplines, as Cannon-Bowers and Salas (2001) recommended. This meta-analysis attempts to integrate different measures of team cognition (shared cognition) from various disciplines to identify which, if any, measure results in the greatest team performance outcome. We analyze six team cognition construct measures in this meta-analysis: shared mental models (SMM), team mental models (TMM), information sharing (IS), transactive memory systems (TMS), cognitive congruence (CC), and group learning (GL). The main questions for this meta-analysis are:

**One attempt to gain better measures of team cognition is to integrate measures across disciplines.**

1. Which team cognition construct produces the best overall effect on performance?
2. How do the measures compare to one another in relation to performance?

A measure of research quality was assessed for each of the research studies included in this meta-analysis. Meta-analyses should be conducted by using quality articles so that there is less of a chance that the effect sizes are found unreliable due to poor design quality (Beretvas, 2010). This quality measure assessed each research study included in this meta-analysis, with the quality of each study coded as low quality, medium quality, or high quality. To determine if any low-quality ranked articles affected the results, a separate analysis was conducted comparing the lower-ranked articles with the higher-ranked articles. This led us to the third research question:

3. What differences are there in the effect sizes reported from those ranked as low-quality research studies compared to those ranked as high quality?

Further descriptions of the six forms of team cognition constructs, along with the different ways in which they were measured in the literature, follow. In addition to the team cognition constructs, the research quality measures are described in more detail under the Assessment of Quality section.

## Shared Cognition Constructs

Individual cognition represents one's sense-making capabilities, one's ability to store information, and one's ability to recall that information at a later time. One model used to identify how an individual's cognitive functions work is the information-processing model, which has the following generic components: the processing objective, information, response, and feedback (Hinsz, Tindale, & Vollrath, 1997). Once a stimulus is encountered, information relating to it, the contextual information, enters the processing objective (Hinsz et al., 1997). If attention is directed to the new information, then the information phase is activated in which this information is encoded, stored, and made available for retrieval (Hinsz et al., 1997). The response phase is activated once an individual decides to act on the new stimulus, which is followed by a feedback mechanism that compares one's stored knowledge with what is actually occurring (Hinsz et al., 1997). In the context of an individual team member, the information-processing model "refers to the individual group member's tendencies to search for, attend to, select, encode, and retrieve information from outside the group boundary, from other group members, and from memory" (De Dreu & Beersma, 2010, p. 1111).

The information-processing model is useful to identify how information is processed at the group level (De Dreu & Beersma, 2010; Hinsz et al., 1997). Much like that of an individual, a team's information-processing model is directed to contextual knowledge, information the group as a whole is attending to (Hinsz et al., 1997). At the team level, information is shared fully in an open format (De Dreu & Beersma, 2010). Information can be recalled from other team members, decreasing the amount of cognitive load that is placed on any individual team member. Team knowledge, for example, can be dispersed among the various team members rather than requiring one team member to store all the information required to complete a task. This shared cognition at the team level is one of the main advantages of using teams for complex tasks.

Effective teamwork and decision making requires team members to hold similar cognitive structures and distinctive knowledge configurations (DeChurch & Mesmer-Magnus, 2010). To study these shared knowledge configurations that team members hold, researchers have studied shared cognitive constructs. Team cognition and team shared cognitive constructs are an emerging field of study identified by the multitude of terms and research studies found in the literature (Akkerman et al., 2007).

Shared cognition, within teams and small groups, represents the collective understanding among team members regarding these members' interactions and team tasks (Hinsz & Ladbury, 2012). The literature describes team cognition as the organized understanding of this collective knowledge among team members (Mohammed & Dumville, 2001), enabling team members to make sense of and acquire knowledge necessary to execute actions (Kozlowski & Ilgen, 2006). Shared cognition provides a way for team members to structure collective meaning and coordinate their activities toward task achievement (Akkerman et al., 2007).

A team's cognitive model transcends each team member's cognitive model, fostering better-quality decision-making capabilities from the collective (Tzeng, 2006). This sharing of cognitions among team members allows teams to complete tasks more efficiently, improving team effectiveness (DeChurch & Mesmer-Magnus, 2010; Hinsz & Ladbury, 2012; Kozlowski & Ilgen, 2006). Team cognition has been shown to be an indicator of team performance, providing team members with a shared understanding of any problems and their resolution techniques (Johnson &

O'Connor, 2008). Shared cognition provides the benefits of being a predictor of learning and performance (Cannon-Bowers & Salas, 2001) while providing teams with better decision-making capabilities. Akkerman et al. (2007) agreed that shared cognition provides a better understanding of how team members learn from one another, improving the team learning process. Shared cognition has been attributed to better task performance, better team processes, and better motivational outcomes (Cannon-Bowers & Salas, 2001) while allowing teams to accomplish their goals more successfully (Hinsz & Ladbury, 2012).

A wide variety of shared cognition constructs can be found in the literature from multiple disciplines. Although these constructs are similar in that each represents a team's shared cognition, they differ in a variety of ways, including how they are defined and measured. The following sections identify how each of the six team cognition constructs (shared mental models, team mental models, information sharing, transactive memory systems, cognitive consensus, and group learning) is defined and measured in the literature selected for this meta- analysis.

## Shared Mental Models (SMM)

The SMM construct represents team members' overlapping mental representation of knowledge, often associated with tasks, equipment, working relationships, and situations (Bossche, Gijselaers, Segers, Woltjer, & Kirschner, 2011). Johnson and Lee (2008) expanded on this definition to include shared knowledge, skill, attitudes, objectives, processes, teamwork components, communication, coordination, roles, and interactions. Bossche et al. (2011) operationalized SMM into two categories, concepts and statements. From their research, they measured SMM concepts as the number of concepts identified by team members, accepting two out of three similar concepts from a team of three. In addition to SMM concepts, SMM statements included two out of three statements from team members, reflecting the same meaning. Alternatively, Johnson and Lee (2008) operationalized SMM into five measures based on team member perceptions of sharedness: team-related knowledge (TK), team-related skill (TS), team-related attitude (TA), team-related dynamicity (TD), and team-related environment (TE).

Outcome measures from Bossche et al. (2011) included perceived team performance, team performance-actual (equity), and team performance-goodwill. Perceived team performance was measured from a questionnaire, while both team performance measures were reported from a simulation game, Steer the Economy (Bossche et al., 2011). Equity referred to the total equity at the end of each game from each team, and goodwill represented an estimate of future profits.

## Team Mental Models (TMM)

Mohammed and Dumville (2001) defined TMM as the "organized understanding of relevant knowledge that is shared by team members"

(p. 89). In congruence with others' studies on TMM, Burtscher, Kolbe, Wacker, and Manser (2011) divided TMM into two separate components: accuracy and similarity. Accuracy represents how accurate team member mental representations are to one another. The accuracy component is often measured against the knowledge from an expert, which was the case for the Burtscher et al. (2011) study. Similarity represents team member shared mental representations, that is, how similar team members' mental representations are to one another. Lim and Klein (2006) expanded on the definition of TMMs to include knowledge of tasks, equipment, roles, goals, and abilities. By this expanded definition, Lim and Klein incorporated a multiple mental model representing TMM accuracy and similarity for both teamwork and task work. Both teamwork and task work mental models were captured through questionnaires and assessed using the structural technique Pathfinder (Lim & Klein, 2006). Team performance was assessed by experts during the test scenario in the study conducted by Burtscher et al. (2011). In the study by Lim and Klein (2006), team performance was measured from a military assessment that was designed to identify the effectiveness of each team.

### Information Sharing (IS)

Information sharing has its roots in the fields of knowledge management and learning organization. Information sharing, as identified by Bontis, Richards, and Serenko (2011), is "the transfer of tacit and explicit knowledge from individuals within the organization to the collective" (p. 240). Internal IS was one of six constructs measured in the questionnaire they included in their study. Garg (2010) identified IS as the ability of team members to share information. Information sharing was measured by a questionnaire, although no specifics were provided on the development of the questionnaire. Kontoghiorghes, Awbrey, and Feurig (2005) addressed IS from a learning organization point of view where IS was described as openly sharing information with employees at all levels of the organization, including teams. Also, from the learning organization perspective, Weldy and Gillis (2010) identified IS as a system allowing access to information and the sharing of information, termed *embedded systems*. The embedded systems scale was measured as one of seven dimensions on the dimensions of the learning organization questionnaire (DLOQ).

Performance measures provided by Garg (2010) included perceived measures from a questionnaire. Team member perceptions, efficiency, and customer focus were measured by Bontis et al. (2011) as performance measures. Efficiency related to how team members believed their workplace had become more efficient, while customer focus related to how team members believed customer focus had changed (Bontis et al., 2011). Two performance measures were included in the Kontoghiorghes et al. (2005) study, rapid change adaptation and quick product introduction, both being perception measures. Rapid change adaptation addressed how the organization is able to adapt to change, while quick product introduction addressed innovation by new product introduction (Kontoghiorghes et al., 2005). Finally, two performance measures were provided in the Weldy and Gillis (2010) study, both from questionnaires and both perception questions: financial performance (the state of financial health for the organization) and knowledge performance (improvements to products and services; Weldy & Gillis, 2010).

**Transactive Memory Systems (TMS)**

Team members often know the action of other team members, an awareness referred to as transactive memory systems (TMS). These systems were introduced by Wegner (1986) from research on married couples. This research expanded to teams and work groups in which an accepted definition of TMS is where team members encode, store, and retrieve relevant information together (Liang, Moreland, & Argote, 1995). Groups that received training as a whole were compared with groups of individuals who received similar training with no attachment to any group in the Liang et al. (1995) study. Groups that trained together were shown to display stronger TMSs compared to groups trained individually (Liang et al., 1995). TMS was divided into three separate dimensions in the Michinov and Michinov (2009) study: specialization, coordination, and credibility. Specialization identifies the expertise among team members, coordination is associated with the ability of team members to work efficiently with one another, and credibility relates to team members' trust of one another's expertise (Michinov & Michinov, 2009). A modified version of the transactive memory scale was used to measure these three dimensions in the Michinov and Michinov (2009) and Michinov, Michinov, and Huguet (2009) studies. The unmodified transactive memory scale was used to measure the same three dimensions in the Pearsall, Ellis, and Stein (2009) study, as well as the Gino, Argote, Miron-Spektor, and Todorova (2010) study.

Performance was based on the number of assembly errors during team experiments for the Liang et al. (1995) study. Group performance was measured in two ways for the Michinov and Michinov (2009) study: performance and performance improvement. Performance was measured from the five tasks that students were given to perform during the semester course, whereas performance improvement measured their improvement during the semester at five different intervals. Pearsall, Ellis, and Stein (2009) measured team performance based on scores received from a computer simulation game that was used as part of the testing procedure. The level of creativity in the end product was measured for the Gino et al. (2010) study. Creativity was assessed by a consensual assessment technique by two independent judges. Finally, Michinov et al. (2009) measured performance by having students draw a complex figure (independently) that they previously had traced as a group. Independent judges measured students on speed and accuracy in which performance scores were added to give one score per team.

### Cognitive Consensus

Kirkman, Tesluk, and Rosen (2001) differentiated between team measures aggregated by individual team members to measures based on team member consensus. Measures based on team member consensus involved team members' meeting to determine a team response to test items. Their input was the gain of consensus scores over aggregated scores. Collins and Smith (2006) looked at consensus from the viewpoint of social climate—the collective (consensus) shared norms, values, and beliefs about employee interactions. This combination consensus of knowledge exchange was measured by a questionnaire designed to evaluate the degree to which employees felt they were able to exchange and combine information.

Team performance was evaluated through team leader evaluations in the Kirkman et al. (2001) study. Team leaders were asked to rate their teams on the following team effectiveness ratings: productivity, customer service, team organizational citizenship behaviors, and proactivity. Performance from the Collins and Smith (2006) study was composed of revenue from new products and services in a one-year time frame and by the percentage of sales growth from the same time frame.

### Group Learning

Group learning has been identified by Pazos, Micari, and Light (2010) as an environment in which "student participation and interaction, facilitation style and student problem-solving" (pp. 191-192) are prevalent. Onwuegbuzie, Collins, and Jiao (2009) also identified group learning (cooperative learning), where students encourage and facilitate one another's achievements. Williams, Duray, and Reddy (2006) looked at collaborative learning in an online course setting in which peers were seen as a source of authority and knowledge. Group interaction was measured using an instrument consisting of 10 items in the Pazos et al. (2010) study. This group interaction scale was based on a spectrum with *individual oriented* on one end of the spectrum and *cooperative* on the other end of the spectrum. A social interaction scale was used to assess individuals' cooperative, competitive, and individualistic perceptions in the Onwuegbuzie et al. (2009) study. Teamwork orientation was measured in the Williams et al. (2006) study to represent the extent to which team members value their membership. Higher teamwork orientation, representing collaborative learning, was believed to result in higher overall team learning in the Williams et al. study.

Self-efficacy was used as a performance outcome in the Pazos et al. (2010) study since it was reported that self-efficacy has been related to students' ability to do well in course work. A survey was used to measure the student self-efficacy scores, with an average of individual scores representing the team's self-efficacy measure. Students were graded on article critiques they submitted as part of their course work in the Onwuegbuzie et al. (2009) study, with group scores assigned from these critique scores as the performance measure. Overall student learning and student team-source learning were used as the outcome variables in the Williams et al. (2006) study. Overall student learning was measured by students' perceptions of their learning. Student team-source learning was measured by a questionnaire designed to assess the perceptions that students had on the skills gained from their interactions with other team members (Williams et al., 2006).

The primary focus of this meta-analysis is to identify which measure of the six team cognition constructs produced the best performance outcome results. This study is unique in that it compares each of the cognition constructs to one another based on the outcome performance.

Summaries of the articles analyzed in this meta-analysis are provided in Table 1, along with their quality rankings (described later), the study predictors, the study outcome measures, the type of measure (perceptual or actual), and the reported effect sizes for each study. As can be seen in Table 1, there are numerous types of performance outcome measures.

The following section briefly describes the use of effect sizes and their importance in meta-analysis studies. The effect sizes used represent performance measures for each of the six team cognition constructs from which the meta-analysis results are based.

## Effect Sizes

Meta-analyses analyze the effect size from different studies that represent the same or similar constructs and their outcomes. An effect size is identified as the "value which reflects the magnitude of the treatment effect or . . . the strength of a relationship between two variables" (Borenstein, Hedges, Higgins, & Rothstein, 2009, p. 3). The most common effect sizes used in meta-analyses are unstandardized or standardized mean differences (d-index), odds-ratio, correlation coefficient (r-index) (Borenstein et al., 2009; Cooper, 2010), proportions, and arithmetic means (Lipsey & Wilson, 2001).

This meta-analysis concentrated on correlation coefficients for each of the six team cognition constructs (SMM, TMM, IS, TMS, CC, and GL) and a team performance outcome. In addition to the correlation coefficients, the unstandardized beta coefficient was used if there was only one predictor variable and the outcome variable was a team performance measure and no correlation coefficient data for these two variables were provided. This univariate regression coefficient, with one predictor and one outcome, is the same as a correlation coefficient (Cohen, Cohen, West, & Aiken, 2003). Each correlation coefficient was then transformed to a standardized measure using the Fisher's $Z$ transformation:

$$Z' = 0.5 \times \ln (1 + r / 1 - r).$$

**TABLE 1 SUMMARY OF ARTICLES ANALYZED IN THE META-ANALYSIS**

| ID NUMBER | RESEARCHERS | QUALITY RANKING | PREDICTORS | OUTCOME | TYPE | REPORTED EFFECT SIZE |
|---|---|---|---|---|---|---|
| Shared mental models | | | | | | |
| 1003101 | Bossche, Gijselaers, Segers, Woltjer, & Kirshner (2011) | High | SMM-Concept<br>SMM–Statement | Perceived team performance<br>Team performance actual<br>Team performance goodwill | P<br>A<br>A | $r = .16$ to .51 |
| 1014101 | Johnson & Lee (2008) | Medium | SMM Team-Related<br>Knowledge<br>Skill<br>Attitude<br>Dynamicity<br>Environment | Team performance | <br>A<br>A<br>A<br>A<br>A | $r = .27$ to .49 |
| Team mental models | | | | | | |
| 1007102 | Burtscher, Kolbe, Wacker, & Manser (2011) | High | TMM-S<br>TMM-A | Team performance | A<br>A | $r = -.08$ to .12 |
| 1131102 | Lim & Klein (2006) | High | Task work MM S<br>Teamwork MM S<br>Task work MM A<br>Teamwork MM A | Team performance | A<br>A<br>A<br>A | $r = .21$ to .42 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Information sharing | | | | | | |
| 1030103 | Bontis, Richards, & Serenko (2011) | Medium | Internal Information Sharing | Efficiency | P | $r = .54$ to .67 |
| | | | | Customer focus | P | |
| 1045103 | Garg (2010) | Low | Information Sharing (composite) | Including customer satisfaction | P | $r = .22$ to .45 |
| | | | | Including effectiveness | P | |
| | | | | Overall performance | P | |
| | | | | Including productivity | P | |
| 1068103 | Kontoghiorghes, Awbre, & Feurig (2005) | High | Open communication and information sharing | Rapid change adaptation | P | $r = .36$ to .52 |
| 1046103 | Weldy & Gillis (2010) | High | Embedded systems | Financial performance | P | $r = .55$ to .63 |
| | | | | Knowledge performance | P | |
| Transactive memory systems | | | | | | |
| 1080104 | Gino, Argote, Miron-Spektor, & Todorova (2010) | High | TMS | Team creativity level | A | $r = .30$ to .70 |
| 1087104 | Liang, Moreland, & Argote (1995) | High | Group trained versus individual trained | Team assembly errors | A | $r = .39$ |
| 1083104 | Michinov & Michinov (2009) | High | Specialization | Performance | A | $r = -.09$ to .42 |
| | | | Coordination | Performance improvement | A | |
| | | | Credibility | | | |

(*continues on next page*)

**TABLE 1** (*Continued*)

| | | | | | | |
|---|---|---|---|---|---|---|
| 1084104 | Michinov, Michinov, & Huguet (2009) | Medium | TMS | Group performance | A | $r = .37$ |
| 1082104 | Pearsall, Ellis, & Stein (2009) | High | TMS<br>Psychological withdrawal<br>Problem-solving coping<br>Avoidant coping | Team performance | A<br>A<br>A<br>A | $r = -.53$ to .5 |
| Cognitive consensus | | | | | | |
| 1137105 | Collins & Smith (2006) | High | Knowledge exchange/ combinations | % sales growth<br>Revenue | A<br>A | $r = .49$ to .54 |
| 1136105 | Kirkman, Tesluk, & Rosen (2001) | High | Consensus gain over aggregate | Productivity<br>Customer service<br>Team OCB | TL-P<br>TL-P<br>TL-P | $r = .22$ to .45 |
| Group learning | | | | | | |
| 1102106 | Onwuegbuzie, Collins, & Jiao (2009) | Medium | Cooperation | Article critique scores | A | $r = -.22$ |
| 1098106 | Pazos, Micari, & Light (2010) | Medium | Group interaction style | Self-efficacy | A | $r = .22$ |
| 1114106 | Williams, Duray, & Reddy (2006) | High | Teamwork orientation | Overall student learning<br>Student team-source learning | P<br>A | $r = .22$ to .45 |

*Note.* P = Perception measure. A = Actual performance measure. TL-P = Team-leader perception measure. S = Similarity. A = Accuracy. OCB = Organization citizenship behaviors.

A number of the studies researched for this meta-analysis included data from multivariate and multiple regression analyses. Lipsey and Wilson (2001) recommended against using the standardized regression coefficients since "each analysis is assumed to be estimating a different population parameter" (p. 67). They further recommended against using analyses from multivariate relationships for meta-analysis studies. Cooper (2010) duplicated this concern by recognizing the diverse nature of regression models with differing variables included in competing models.

A number of the studies provided more than one correlation coefficient for the relationships between the shared cognition construct and the team performance output. In cases where more than one correlation coefficient is provided in a single study, these coefficients should not all be included in the meta-analysis since these measures are dependent measures (Borenstein et al., 2009; Cooper, 2010; Lipsey & Wilson, 2001). Instead, the researcher is to either choose one effect size for the meta-analysis or average the effect sizes and use the average effect size for the meta-analysis (Borenstein et al., 2009; Cooper, 2010; & Lipsey & Wilson, 2001). For this meta-analysis, it was determined that the average effect size would be incorporated into the meta-analysis where more than one effect size was coded within the same study.

## Method

### Data Collection Methods

This meta-analysis concentrated on team shared cognition measures. Six forms of team cognition measures were analyzed: shared mental models (SMM), team mental models (TMM), information sharing (IS), transactive memory systems (TMS), cognitive consensus (CC), and group learning (GL). The studies were pooled from the national bibliographic database, ERIC-EBSCOhost. The search criteria for each of the forms of team shared cognition follow. The time period for each search was set at January 1990 through April 2012. The beginning date was selected with the belief that most recent literature on shared cognition would fall within this time period.

The first search conducted was for TMMs. The term "Team Mental Models" was entered, the criterion "in abstract," along with the criterion for "English" articles. The initial search resulted in 38 articles; 12 of these were not accessible. Of these 38 articles, 25 were found to be relevant to the meta-analysis after reviewing their abstracts. Four had quantitative data and could be used for this meta-analysis. After analyzing these four articles, it was discovered that both TMM and SMM articles were classified under the "team mental models" search. Of the four remaining articles, two were classified as being related to TMM and two as being related to SMM. We therefore had two articles each for TMM and for SMM.

The second search was for information sharing. The term "information sharing" was entered with the criterion "in abstract" selected along with "English." The initial criteria produced 832 articles, which were reduced through an abstract review by excluding K-12 education articles, classroom articles, and international education articles. Only articles including organizational, higher education, and training were selected. This produced 53 articles. Of these 53, only 5 provided quantitative data that could be used for this meta-analysis. One of the 5 articles did not provide adequate quantitative data, resulting in 4 articles for the shared cognition construct of information sharing.

The third search, for transactive memory systems, was conducted using the search term "transactive memory" with the criteria "in abstract" selected along with "English." The initial search resulted in 8 articles. Of these 8 articles, 4 provided quantitative data that could be used for this meta-analysis.

The fourth search conducted was for group learning. The search term "group learning" was entered with the criterion "in abstract" selected along with "English." This initial search resulted in 4,572 articles. This search was refined to include "academic journals" only, resulting in 2,556 articles, and then further reduced by changing the criterion "in abstract" to "in title," resulting in 577 articles. In a review of the abstracts, articles relating to K-12 education, classroom, and international education were excluded. Articles relating to organizational or higher education were included. The final article total resulted in 38 articles in which 9 articles provided quantitative data for this meta-analysis. Three of these 9 articles provided adequate information for this meta-analysis.

The final search, for cognitive consensus, was conducted. The search term "cognitive AND consensus" was entered with the criterion "abstract" selected along with "English." A total of 67 articles were produced in which 3 provided adequate quantitative data for this meta-analysis.

In total, 18 articles were selected for this meta-analysis: 2 for TMM, 2 for SMM, 4 for IS, 4 for TMS, 3 for GL, and 3 for CC.

**Sample Summary**

The sample drawn from the search resulted in 13,491 participants with 768 teams in all. Of these totals, 1,664 participants were males and 1,101 females, with an estimated average age of around 21 years. Not all of the retrieved articles provided complete sampling data for their research. This resulted in not being able to calculate the total number of males and females, as well as the average of all participants. This summary information comes from the articles retrieved from the search.

For the SMM construct, there were 101 participants with 32 teams; 62 participants were male, and 39 were female, with an average age of 23.5 years. All of the articles for SMM were from the higher education sector. For the TMM construct, there were 610 participants with 102 teams; 585 were male, and 25 were female, with an average age of 20.4. The sectors represented for the TMM construct included the health industry and the military (international). The military study was made up of all males, accounting for the high ratio of males to females for the TMM construct.

The IS construct consisted of 9,779 participants with four groups. Each study under the IS construct consisted of only one group, questioning an organization's department or a specific type of employee (IT service employee) rather than comparing actual teams. Of these 9,779 participants, only one study documented the gender makeup, with 101 males and 42 females. No average age was provided from either of the studies for the IS construct. The IS studies represented the private sector, which included business, telecommunications, IT, management, health industry, manufacturing, and the service industry.

The TMS construct produced 964 participants with 316 teams. There were 455 males and 509 females, with an average age of 21.3 years. All of the TMS studies represented higher education, with two of them representing higher education from an international university.

For the construct CC, there were 1,090 participants with 99 teams. No data were reported regarding the age or gender of the participants for either of the two studies for the CC construct. The sectors represented by these two studies were textiles, high-tech manufacturing, insurance, engineering, software, management, and consulting.

The GL construct resulted in 947 participants and 215 teams, with 461 males and 486 females. The average age for the GL construct was estimated to be 21.6 years (not all studies reported age). All of the GL studies represented the higher education sector.

## Assessment of Quality

To document the quality of the research studies included in this meta-analysis, a measure of each study's quality was recorded. These quality measures are provided to support the findings from this meta-analysis. For example, data provided from studies identified as high in quality should be viewed as being more valid than data provided from studies identified as low in quality. In addition, the quality measures were used to analyze the calculated effect sizes to see if there were any differences among the different quality groupings.

The quality measure used in this meta-analysis was a modified version of Gall, Gall, and Borg's (2010) Questions to Ask Yourself When Evaluating a Report of a Quantitative Study. The quality evaluation is provided in the Appendix at the end of this article. This quality evaluation was divided into four sections: Introduction, Method, Results, and Discussion.

Among the questions in the Introduction were these:

- Is the literature review section of the report sufficiently comprehensive?
- Does the literature review include studies that you know to be relevant to the problem?

- Is each variable in the study clearly defined?

Questions relating to the Method section include the following types:

- Is each measure appropriate for the sample?
- Is each measure in the study sufficiently reliable for its intended purpose?

The Results section concentrated on questions pertaining to whether appropriate statistical techniques were used and whether the practical significance was reported—for example:

- Did the researchers provide a reasonable explanation of the findings?
- Did the researchers draw sound implication for practice from their findings?

There were 18 questions, each measured on a 3-point scale from 0 to 2 (0 = *No*, 1 = *Somewhat*, 2 = *Yes*). With a total possible score of 36, the quality scores were coded into a categorical variable with three quality scales: Low-Quality Ranking (below 18), Medium-Quality Ranking (between 18 and 27), and High- Quality Ranking (above 27). Each article was evaluated by the researcher; 9 of the 18 articles were also evaluated by a second researcher (a third-year doctoral student) using the same quality evaluation measure. The interrater reliability between these two measures resulted in a calculation of 80% (Cronbach's alpha standardized =.800).

Of the 19 articles for this meta-analysis, 1 was classified as low-quality ranking, 5 as medium-quality ranking, and 12 as high-quality ranking. Figure 1 shows the frequency chart for the three quality ranking scales, and Figure 2 shows the frequency chart for the total quality scores.

### Statistical Methods

For this meta-analysis a random-effects model was conducted as opposed to a fixed-effects model. A fixed-effects model is used when studies are functionally identical to one another, compared to a random-effects model, which is used when various researchers operate independently, making it less likely that each study is identical to one another (Borenstein et al., 2009). A random-effects model was incorporated since each of the research studies varied from one another by design, sample, measures, and researchers. The procedures for these calculations are summarized from Borenstein et al. (2009) and Lipsey and Wilson (2001).

## Results

### Assessment of Heterogeneity

A test of heterogeneity was conducted to determine whether the variance calculated (true variance) was more than what would be

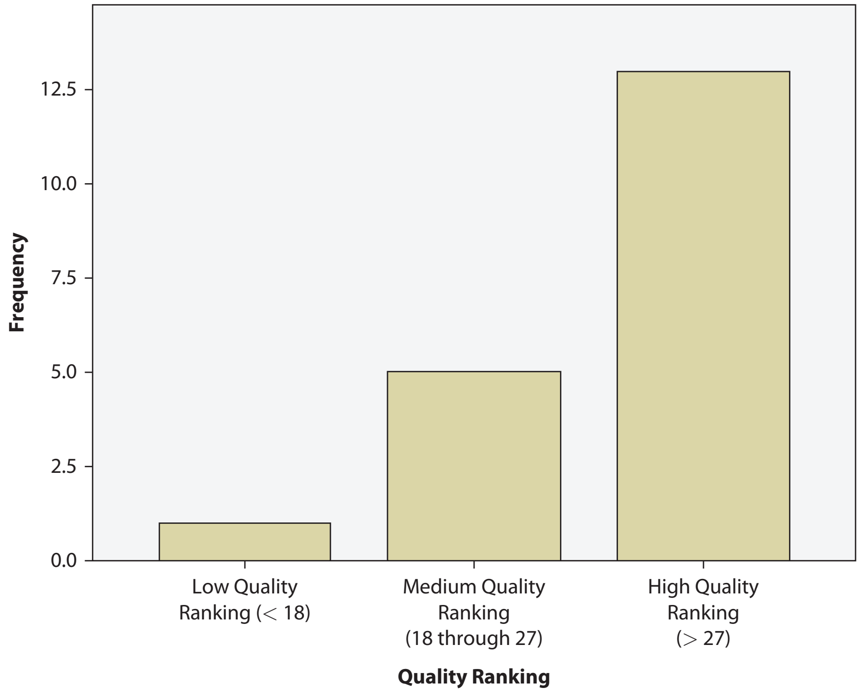


**FIGURE 1.** FREQUENCY CHART FOR QUALITY RANKINGS

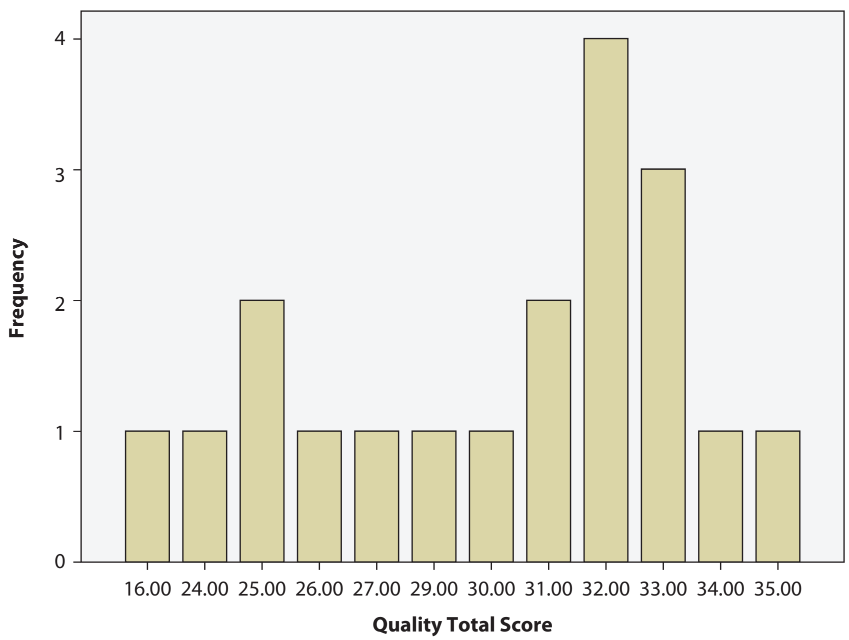


**FIGURE 2.** FREQUENCY CHART FOR TOTAL QUALITY SCORES

expected from random error. To test for heterogeneity, the within-study variance and the between-study variance were determined. The weight assigned to each study is represented by $W$ and was calculated as the inverse of the variance for a particular study. The calculated correlation, in this case the Fischer's $z$ score, is identified as $Y$. The degrees of freedom ($df$) equal the number of studies ($k$) minus 1 ($df = k - 1$). The excess variation is identified as $Q - df$ (Borenstein et al., 2009).

The test of homogeneity was conducted using the fixed-effects values. It is tested by the null hypothesis that all studies share a common effect size (Borenstein et al., 2009). Table 2 shows the calculations for the fixed effects for all the effect sizes in the meta-analysis.

To test the null hypothesis for homogeneity, a $Q$ value of 177.53 was calculated with a $df = 17$. Using a chi square test, the critical value for this test was 27.587. Since the calculated $Q$ was greater than the critical value for $df = 17$, the observed variation is greater than expected by error, thus rejecting the null that the within-study variances are not different. Thus, this sample is a sample of heterogeneity in which the variance is more than what is expected from error.

For the fixed effects, the weighted mean was calculated as .656, $s^2 = .0000939$, $SE = .00969$. The 95% CI [.637, .675] excludes zero, identifying this confidence interval as being significant. The calculated $z$-score for the fixed effects was 67.68, greater than the significant $z$-score of 1.96 with an alpha of .05 for a two-tailed test. The null hypothesis that the fixed-effects weighted mean is equal to the population mean of zero was rejected, indicating that there is a relationship between the shared cognition weighted means and team performance.

Once the homogeneity test had been rejected, the random effects were calculated to determine the between-study variance. The random effects were calculated, producing a between-study variance ($T^2$) of .055 with a standard deviation of $T = .235$. Table 3 shows the calculated values for each of the random effects for this meta-analysis.

The new weight assigned to each study was calculated using the total variance, within-study variance plus between-study variance ($V_T = V_W + V_B$). The random-effects weighted mean ($W^*$) was calculated as .359, $V_T = .0041$, $SE = .0644$. The random effects resulted in a 95% CI [.233, .485], excluding zero, which identifies this confidence interval as being significant. The calculated $z$-score for the random effects was calculated to be 5.57 ($p < .001$), greater than the significant $z$-critical value of 1.96 with an alpha of .05 for a two-tailed test. By being significant, the null hypothesis that the random-effects weighted mean is equal to the population mean of zero was rejected, indicating that there is a relationship in the population between the six shared cognition constructs and team performance.

Values from the random effects were transformed from the standardized format (Fisher's $z$) to a regular correlation format, *summary effect*, to compare with the originally reported values for the effect sizes

**TABLE 2 FIXED EFFECTS FOR ALL EFFECT SIZES**

| STUDY ID | Y | $V_W$ | W | WY | $WY^2$ | $W^2$ |
|---|---|---|---|---|---|---|
| 1003101 | .42 | 0.042 | 24 | 10.7 | 4.23 | 576 |
| 1014101 | .38 | 0.5 | 2 | 0.77 | 0.29 | 4 |
| 1007102 | .02 | 0.036 | 28 | 0.56 | 0.01 | 784 |
| 1131102 | .30 | 0.015 | 68 | 20.12 | 5.96 | 4624 |
| 1045103 | .33 | 0.018 | 57 | 19.03 | 6.36 | 3249 |
| 1030103 | .70 | 0 | 9057 | 6348.9 | 4450.62 | 82,029,249 |
| 1068103 | .47 | 0.002 | 513 | 241.94 | 114.29 | 263,169 |
| 1046103 | .68 | 0.007 | 140 | 94.87 | 64.36 | 19,600 |
| 1087104 | .41 | 0.011 | 87 | 35.52 | 14.48 | 7569 |
| 1083104 | .19 | 0.024 | 42 | 7.93 | 1.50 | 1764 |
| 1082104 | −.01 | 0.013 | 80 | −0.8 | .008 | 6400 |
| 1080104 | .55 | 0.012 | 86 | 47.24 | 25.92 | 7396 |
| 1084104 | .39 | 0.024 | 41 | 15.93 | 6.17 | 1681 |
| 1136105 | .32 | 0.011 | 87 | 27.69 | 8.81 | 7569 |
| 1137105 | .57 | 0.008 | 133 | 75.75 | 43.14 | 17,689 |
| 1098106 | .23 | 0.006 | 157 | 35.78 | 8.15 | 24,649 |
| 1102106 | −.22 | 0.043 | 23 | −5.14 | 1.15 | 529 |
| 1114106 | .35 | 0.038 | 26 | 9.06 | 3.16 | 676 |
| Total | | | 10,651 | 6985.21 | 4758.61 | 82,397,177 |

**TABLE 3 RANDOM EFFECTS FOR ALL EFFECT SIZES**

| STUDY ID | Y | $V_W$ | $V_B$ | $V_T$ | W* | W * Y |
|---|---|---|---|---|---|---|
| 1003101 | .42 | 0.042 | 0.0551 | 0.097 | 10.302 | 4.327 |
| 1014101 | .38 | 0.5 | 0.0551 | 0.555 | 1.802 | 0.692 |
| 1007102 | .02 | 0.036 | 0.0551 | 0.091 | 10.980 | 0.220 |
| 1131102 | .30 | 0.015 | 0.0551 | 0.070 | 14.271 | 4.224 |
| 1045103 | .33 | 0.018 | 0.0551 | 0.073 | 13.685 | 4.571 |
| 1030103 | .70 | 0 | 0.0551 | 0.055 | 18.158 | 12.729 |
| 1068103 | .47 | 0.002 | 0.0551 | 0.057 | 17.521 | 8.270 |
| 1046103 | .68 | 0.007 | 0.0551 | 0.062 | 16.110 | 10.923 |
| 1087104 | .41 | 0.011 | 0.0551 | 0.066 | 15.135 | 6.175 |
| 1083104 | .19 | 0.024 | 0.0551 | 0.079 | 12.647 | 2.390 |
| 1082104 | −.01 | 0.013 | 0.0551 | 0.068 | 14.690 | −0.147 |
| 1080104 | .55 | 0.012 | 0.0551 | 0.067 | 14.909 | 8.185 |
| 1084104 | .39 | 0.024 | 0.0551 | 0.079 | 12.647 | 4.907 |
| 1136105 | .32 | 0.011 | 0.0551 | 0.066 | 15.135 | 4.817 |
| 1137105 | .57 | 0.008 | 0.0551 | 0.063 | 15.855 | 9.029 |
| 1098106 | .23 | 0.006 | 0.0551 | 0.061 | 16.374 | 3.731 |
| 1102106 | −.22 | 0.043 | 0.0551 | 0.098 | 10.196 | −2.281 |
| 1114106 | .35 | 0.038 | 0.0551 | 0.093 | 10.744 | 3.744 |
| Total | | | | 1.801 | 241.16 | 86.51 |

(Borenstein et al., 2009). The summary effect of the correlation is .344 with a 95% CI [.228, .450]. This summary effect (corrected correlation) shows a positive association between the team cognitive constructs and team performance; this positive association is significant.

To determine the proportion of variance, the $I^2$ statistic was calculated. This value helps to answer the question: "What proportion of the observed variance reflects real differences in effect size?" (Borenstein et al., 2009, p. 116). For the effect sizes in this meta-analysis, $I^2$ indicated that 90.42% of observed variance was real. Borenstein et al. (2009) provided that $I^2$ values greater than 75% are classified as being high, indicating that most of the observed variance is real.

To summarize the statistics identified above, the following points are provided from Borenstein et al. (2009, p. 120):

1. The Q statistic and its $p$-value serve as a test of significance.
2. The estimate $T^2$ serves as the between-studies variance in the analysis and the estimate of $T$ serves as the standard deviation of the true effects.
3. $I^2$ is the ratio of true heterogeneity to total variation in observed effects.

The prediction interval for the weighted mean ($M^*$) can be calculated to determine the estimated dispersion of expected effect sizes. This dispersion represents the estimated effect size values that can be expected for these six shared cognitive constructs when testing performance outcome measures. The prediction interval was different from the confidence interval for the weighted mean that was reported earlier (.233 to .485). This confidence interval represents the accuracy of the weighted mean of .359, meaning that each weighted mean is expected to fall within the range of .233 and .485.

With a $df = 16$, the critical $t$-value is 2.120 for a two-tailed test at an alpha of .05. The prediction interval for the weighted mean was calculated to be $-0.157$ for the lower interval and 0.875 for the upper interval. This prediction interval indicates that the six shared cognitive constructs will produce (95% of the time) effect sizes that range from $-0.157$ to 0.875.

**Shared Cognition Comparisons**

In order to address the research questions posed at the beginning of this meta-analysis a comparison between the individual team cognition measures was conducted. At the beginning of this meta-analysis the researchers were interested in answering two research questions: (1) Which shared cognition construct produces the best overall effect on performance? and (2) How do the measures compare to one another in relation to performance? The calculated weighted effect sizes for each of the team cognition constructs are provided in Table 4, along with the weighted mean calculations for each of the six-shared cognitive constructs in Table 5.

**TABLE 4 EFFECT SIZE CALCULATED TOTALS FOR INDIVIDUAL SHARED COGNITIVE CONSTRUCTS**

| CONSTRUCT | $V_B(T^2)$ | W* | W*Y | $W^*Y^2$ | $W^{*2}$ |
|---|---|---|---|---|---|
| SMM | 0 | 25.81 | 10.77 | 4.49 | 570.90 |
| TMM | .0128 | 56.41 | 11.04 | 3.16 | 1710.24 |
| IS | .0222 | 145.64 | 82.70 | 49.91 | 5540.35 |
| TMS | .0413 | 86.98 | 26.77 | 11.70 | 1527.85 |
| CC | .0220 | 63.54 | 28.59 | 13.86 | 2023.53 |
| GL | .0349 | 50.97 | 7.47 | 3.58 | 949.48 |

**TABLE 5 WEIGHTED MEAN SUMMARY FOR INDIVIDUAL SHARED COGNITIVE CONSTRUCTS**

| | SMM | TMM | IS | TMS | CC | GL |
|---|---|---|---|---|---|---|
| M* | 0.417 | 0.196 | 0.568 | 0.308 | 0.450 | 0.147 |
| $V_{M*}$ | 0.039 | 0.018 | 0.007 | 0.011 | 0.016 | 0.020 |
| $SE_{M*}$ | 0.197 | 0.133 | 0.083 | 0.105 | 0.126 | 0.140 |
| $LL_{M*}$ | 0.031 | −0.065 | 0.405 | 0.101 | 0.204 | −0.128 |
| $UL_{M*}$ | 0.803 | 0.456 | 0.730 | 0.514 | 0.696 | 0.421 |
| $Z_{M*}$ | 2.119 | 1.472 | 6.853 | 2.919 | 3.585 | 1.047 |
| $\rho$ | 0.017 | 0.071 | <.001 | <.001 | <.001 | 0.148 |
| Q | 0.002 | 1.509 | 32.691 | 14.817 | 3.319 | 4.812 |
| r* | 0.394 | 0.193 | 0.513 | 0.298 | 0.422 | 0.146 |
| LLr* | 0.032 | −0.065 | 0.384 | 0.101 | 0.201 | −0.127 |
| ULr* | 0.666 | 0.427 | 0.623 | 0.474 | 0.602 | 1.398 |

The values provided in Table 4 used the same calculations as those in the test of heterogeneity. The main difference is that for the test of heterogeneity, all 18 studies were included as one comparison, resulting in the summed values for all 18 studies. For these individual construct calculations, only the construct values were summed rather than all 18 studies. This resulted in a separate between-study variance ($T^2$) for each construct, which produced a weighted effect size ($W^*$) for each effect for that cognitive construct. The weighted values were then summed and used to calculate the mean effect ($M^*$, $V_{M^*}$, and $SE_{M^*}$) for each cognitive construct, along with its corresponding confidence interval estimate (Table 5).

The weighted mean for each cognitive construct was calculated along with the estimated confidence interval for each effect size. Next, the transformed correlation was calculated (Fisher's $z$ to correlation). Of the six cognitive constructs, four of the weighted means were found to have a statistically significant calculated $Z$-value; SMM (.417), IS (.568), TMS (.308), and CC (.449). No statistically significant results were found for the weighted means for either TMM (.196) or GL (.147), indicating that the weighted means for these two cognitive constructs did not differ from zero.

For each of the six shared cognitive constructs, the corrected correlation values were all positive, ranging from a low of .147 for GL with a high of .513 for IS. A comparison was conducted for each of these constructs using the comparison procedures outlined by Borenstein et al. (2009). This method used a $z$-test to compare the two mean effects, comparing each paired shared cognitive constructs. In order to compare all possible mean effects, a matrix was set up with a total comparison of 15 mean effects. This comparison matrix and the calculated $z$-values are provided in Table 6.

To compare two mean effects, the first step was to calculate the difference between the two mean effects, $\text{Diff}^* = M^*_B - M^*_A$. The $z$-value was then calculated by dividing this difference by the calculated standard error, $SEDiff^* = \text{SQRT}(V_{MA^*} + V_{MB^*}$; Borenstein et al., 2009).

For the calculations provided in Table 6, the mean effect for the first column was subtracted from the second, third, fourth, fifth, or sixth column, depending on which calculation was being performed. For example, the first calculated $z$-value is $-.932$ which is the product of, $\text{Diff}^* = M^*_{TMM} - M^*_{SMM}$. By being negative, this calculated $z$-value indicates that the mean effect for TMM is smaller than the mean effect for SMM.

To be significant, the calculated $z$-value needs to be greater than the critical $z$-value of 1.96, alpha $= .05$, two-tailed. Two $z$-values were found to be significant. The first significant difference was between IS and TMM, $z = 2.372$, $p = 0.018$, indicating that the weighted mean for IS was significantly different from (greater than, since the $Z$-value was positive) the weighted mean for TMM, $p < .05$, two-tailed. The second significant difference was between GL and IS, $z = -2.588$, $p = 0.0097$, indicating that the weighted mean for GL was significantly different from (less

**TABLE 6 COMPARISONS BETWEEN SHARED COGNITIVE EFFECTS WITH CALCULATED Z-VALUES**

| RANDOM-EFFECTS MODEL (SEPARATE ESTIMATES OF $T^2$), CALCULATED $Z$-VALUES | | | | | | |
|---|---|---|---|---|---|---|
| | **SMM** | **TMM** | **IS** | **TMS** | **CC** | **GL** |
| SMM | – | | | | | |
| TMM | −0.932 | – | | | | |
| IS | 0.705 | $^{**}$2.372 | – | | | |
| TMS | −0.490 | 0.659 | $^{*}$−1.939 | – | | |
| CC | 0.140 | 1.389 | −0.784 | 0.867 | – | |
| GL | −1.120 | −0.254 | $^{**}$−2.588 | −0.919 | −0.589 | – |

Significant at $^{*}p < .10$, $^{**}p < .05$.

than, since the $Z$-value was negative) the weighted mean for IS, $p < .05$, two-tailed. In addition to the significant findings at the $p = .05$ level, one significant finding at the $p = .10$ level was identified. This significant level at $p < .10$ is being reported here since we are concerned with the differences between constructs, even though the significance level of $p < .10$ is higher than the significance level used primarily as the standard ($p < .05$) for this meta-analysis. The significant finding at the $p < .10$ was between TMS and IS, $z = -1.939$, $p = 0.0525$, indicating that the weighted mean for TMS was marginally significantly different from (less than, since the Z-value was negative) the weighted mean for IS, two-tailed.

From this comparison, the one team cognition construct that stood out was that of IS, with statistical findings greater than the constructs of TMM, GL, and TMS. The two shared cognitive constructs that were not statistically different from IS were SMM and CC; neither of these constructs was found to be significantly different from TMM, GL, or TMS. However, these findings did indicate that SMM had a higher calculated Z-value than TMM, and GL. In addition to the findings for SMM, the calculated Z-values for CC were higher than those for SMM, TMM, TMS, and GL.

### Quality Ranking Comparison

The final research question posed at the beginning of this meta-analysis was related to the quality of the research studies used in the analysis. A quality score was measured for each of the 18 studies in this meta-analysis. (For a summary of these quality scores, see the "Assessment of Quality" section). This comparison test assessed the studies ranked as high quality and compared them with the studies ranked as being of low and medium quality. The low-quality and medium-quality categories were recoded into one category since only one study ranked in the low-quality category. This recoding allowed the 12 high-quality studies to be compared against the 6 low-quality and medium-quality studies. This comparison helped shed light on the third research question:

3. What differences are there in the effect sizes reported from those ranked as low-quality studies compared to those ranked as high-quality studies?

For this comparison test, the weighted values were summed, once for the low- and medium-quality studies and once for the high-quality studies. The between-study variance ($T^2$) for the low- and medium-quality studies was 0.109, with a within-study variance for the high-quality studies being 0.026. Table 7 provides the calculated values for the two groups: low- and medium-quality studies and high-quality studies.

For the values provided in Table 7, the mean effect for the high-quality studies was subtracted from the mean effect for the low- and medium-quality studies. This resulted in a calculated $\text{Diff}^* = M^*_{Low/Med} - M^*_{High}$

| TABLE 7 | WEIGHTED MEAN SUMMARY FOR LOW/MEDIUM- AND HIGH-QUALITY RANKED ARTICLES | |
|---|---|---|
| | **LOW / MEDIUM** | **HIGH** |
| M* | 0.316 | 0.391 |
| $V_{M*}$ | 0.024 | 0.002 |
| $SE_{M*}$ | 0.155 | 0.048 |
| $LL_{M*}$ | 0.012 | 0.298 |
| $UL_{M*}$ | 0.621 | 0.484 |
| $Z_{M*}$ | 2.034 | 8.212 |
| $\rho$ | 0.022 | $<.001$ |
| Q | 64.928 | 38.433 |
| r* | 0.306 | 0.372 |
| LLr* | 0.012 | 0.289 |
| ULr* | 0.552 | 0.450 |

$= 0.3795 - 0.316 = 0.0633$. The standard error was calculated as being .166, $z = .3812$ ($z = .0633/.166$), $p = 0.703$. To be significant, the calculated $z$-value needs to be greater than the critical $z$-value of 1.96, alpha $= .05$, two-tailed. Since this $z$-value was less than the $z$-critical value, the null hypothesis that the two groups are equal was retained, indicating that these groups are not statistically different from one another.

The prediction intervals were calculated for both the low- and medium-quality studies and the high-quality studies. The lower and upper prediction limits for the low- and medium-quality studies were calculated to range from $-0.697$ to 1.330, respectively. The lower and upper prediction limits for the high-quality studies were calculated to range from 0.0023 to 0.767. These prediction limits show that the range of the effect sizes for the high-quality studies falls within the range calculated for the low- and medium-quality studies. This overlap supports the nonsignificant finding presented above.

## Discussion

The test of homogeneity of all the shared cognition studies included in this meta-analysis showed that the variance was greater than what is expected from error alone. By being a heterogeneous sample, the random effects were calculated so that analyses could be conducted. This was done primarily to account for this additional variance. In keeping with the recommendations provided by Lipsey and Wilson (2001) on reporting results for meta-analyses, this section looks at why the study effects differ.

The primary focus of this meta-analysis was to compare six shared cognition constructs (SMM, TMM, IS, TMS, CC, and GL) and their association with team performance. Relating to the first two research questions, the IS construct was statistically significant compared to the constructs of TMM and GL at the $p < .05$ level and marginally significant compared to the TMS construct at the $p < .10$ level. No other significant findings were identified between the other cognition constructs. Following IS, the SMM construct showed higher associations with performance compared to TMM and GL, while the construct of CC showed higher associations with performance compared to SMM, TMM, TMS, and GL, although neither was statistically significant.

The IS construct provides team members with the tools, resources, and environment that are conducive to sharing information with other team members. Wittenbaum, Hubbell, and Zuckerman (1999) indicated that it was uncommon for group members to pool their unique knowledge effectively; typically team members discuss common, shared knowledge. By discussing only shared knowledge, new knowledge is unlikely to surface, reducing a team's ability to solve problems and to be innovative. Stasser and Titus (1985) and Stasser, Vaughan, and Stewart (2000) identified that pooling unshared knowledge is critical to decision making in teams. Since the IS construct addressed the sharing of tacit and explicit knowledge, which is comparative to unshared and shared knowledge for teams, it is possible that the IS construct was better able to use team members' unshared knowledge compared to the other constructs in this meta-analysis.

By comparison, SMM also looked at assessing knowledge, but knowledge that was more specific to team task work. Alternatively, CC assessed the consensus of the team's knowledge. The consensus measure could prove to be less effective than IS if the consensus of the group was that of shared knowledge rather than unshared knowledge.

The least effective measures were shown to be TMM, TMS, and GL. TMM looked at both similarity and accuracy measures of team knowledge related to both task work and teamwork. In the study by Burtscher et al. (2011), the accuracy measure was negatively correlated with performance. For future research, looking separately at each of these two measures, similarity and accuracy, could be beneficial. Identifying which measure, similarity or accuracy, is a better predictor of performance could show where a team's performance could be improved. These measures could also be compared against the measures from IS to determine if TMM-accuracy or TMM-similarity is a comparable predictor of team performance.

Transactive memory systems look at the ability of team members to encode, store, and retrieve (Liang et al., 1995) knowledge while performing a particular task. While TMS may be beneficial when performing a task that team members have performed previously, it may not be the best measure to capture new knowledge among team members. This could be the reason that TMS was significantly lower compared to IS.

Group learning included student participation and interaction, which could be conducive to sharing new knowledge among members. However, the Williams et al. (2006) study placed students in a situation where they were perceived to be a source of authority and knowledge. Placing a team member in a situation does not guarantee that new knowledge will be generated. One other potential downfall for the GL construct was that the length of discussions was not measured. Hollingshead (1996) suggested that prolonging discussion leads to discussing more unshared information. Increasing the length of discussion among student groups could prove to be beneficial to overall student learning. These potential explanations could contribute to explaining why GL was a lower predictor of performance compared to all other constructs (IS, SMM, TMM, TMS, and CC). Future research efforts could compare different situations in which knowledgeable and nonknowledgeable team members are perceived as being the source of knowledge. Future research could also vary the length of discussion between groups to see if that length is positively associated with overall student learning.

## Limitations

One limitation for this meta-analysis is the small number of studies. Of the 5,517 articles initially captured, only 18 were found relevant to this meta-analysis with adequate empirical data. Having a small size can reduce the power for the overall analysis and could produce higher variances compared to having a larger sample. Selecting a larger number of categories—in this case, six shared cognitive constructs—helps to spread this variability among studies. However, the number of studies per category could be considered low. The literature search for this meta-analysis followed the guidelines provided by Cooper (2010), who indicated that a complete literature search should include the following:

1. A search of reference databases
2. A perusal of relevant journals
3. The examination of references in past primary research and research synthesis and
4. Personal contact with active and prominent researchers. (p. 78)

With the exception of this final recommendation, the current study attempted to collect effect sizes representing associations between each of the six shared cognition constructs and team or departmental performance outcomes. This resulted in a smaller-than-expected sample size. Due to this size, the differences identified in this meta-analysis can only be highlighted with explanations as to why these differences may exist. However, these results cannot be generalized to any population due to this small size. The results here are more informative in nature than inferential or causational.

The outcome measures included in this meta-analysis are broad, consisting of task-based outcome, behavioral outcome, business outcome, and perceptual outcome measures. Although these outcome measures might be considered too broad by some, they were identified from the literature and not selected by the researchers. The attempt was to identify the effects that the six shared cognition constructs had on performance outcome measures with minimal limitations on the outcome measures themselves. Selection of only one specific outcome measure would have resulted in a sample size too small for analysis.

Most of the research studies in this meta-analysis are from peer-reviewed journals; some were from dissertations. Publication bias is possible in this meta-analysis, showing primarily only statistically significant results. However, some measures in this meta-analysis provided multiple outcome measures to represent one construct, thus producing both statistically significant findings as well as nonstatistically significant findings. This fact may only partially reduce the potential for publication bias. We recognize that some publication bias may be present in this meta-analysis.

## Conclusion

The small sample size from this meta-analysis was primarily a function of the emerging nature of these team cognition constructs. Cannon-Bowers (2001) had indicated that interest in researching these emerging constructs had only surfaced within the past ten years, placing the beginning of exploring these emerging constructs at around 1991. For example, transactive memory systems were introduced by Wagner in 1986, and it was not until much later that research studies measured TMS against team performance. In addition, team mental models were first conceptualized by Klimoski and Mohammed in 1994, some of the first tests relating shared mental models against team effectiveness were conducted by Cannon-Bowers and Salas in 2001, and information sharing was introduced to the team literature by Hinz et al. in 1997 and by Stasser and Titus in 1985. Going back for additional data prior to 1990, the selected data retrieval cut-off date for this meta-analysis, would not produce any related sources of new data. This point leads to two conclusions: team cognition constructs are new and emerging constructs, and more research needs to be conducted to better understand them.

This meta-analysis attempted to shed light on the methods that have emerged to measure team cognition. Also, response to the concerns identified by Cannon-Bowers and Salas (2001) and by Akkerman et al. (2007) calling for better clarity in defining team cognition constructs was addressed. Results also attempted to identify which team cognition construct measures are better at predicting performance in response to Cannon-Bowers and Salas's (2001) call for better measures. We recommend expanding research on the team cognition constructs of information sharing, shared mental models, and cognitive congruence. More research is needed in these areas, and this meta-analysis contributes to the literature by beginning this exploration into team cognition constructs and identifies the need for more research on team cognition constructs with a focus on the outcome of team performance.

## References


*References marked with an asterisk indicate studies included in the meta-analysis.* The in-text citations to studies selected for meta-analysis are not preceded by asterisks.

Akkerman, S., Van den Bossche, P., Admiraal, W., Gijselaers, W., Segers, M., Simons, R.-J., & Kirschner, P. (2007). Reconsidering group cognition: From conceptual confusion to a boundary area between cognitive and socio-cultural perspectives? *Educational Research Review, 2*, 39–63. doi:10.1016/j.edurev.2007.02.001

Beretvas, N.S. (2010). Meta-analysis. In G.R., Hancock & R.O., Mueller (Eds.), *The reviewer's guide to quantitative methods in the social sciences* (pp. 255–263). New York, NY: Routledge.

*Bontis, N., Richards, D., & Serenko, A. (2011). Improving service delivery: Investigating the role of information sharing, job characteristics, and employee satisfaction. *Learning Organization, 18*(3), 239–250. doi:10.1108/09696471111123289

Borenstein, M., Hedges, L.V., Higgins, J.P.T., & Rothstein, H.R. (2009). *Introduction to meta-analysis*. West Sussex, UK: Wiley.

*Bossche, P.V., Gijselaers, W., Segers, M., Woltjer, P., & Kirschner, P. (2011). Team learning: building shared mental models. *Instructional Science, 39*, 283–301. doi:10.1077/s11251-010-9128-3

*Burtscher, M.J., Kolbe, M., Wacker, J., & Manser, T. (2011). Interactions of team mental models and monitoring behaviors predict team performance in simulated anesthesia inductions. *Journal of Experimental Psychology: Applied, 17*(3), 257–269. doi:10.1037/a0025148

Cannon-Bowers, J.A., & Salas, E. (2001). Reflections on shared cognition. *Journal of Organizational Behavior, 22*(2), 195–202. doi:10.1002/job.82

Cohen, J., Cohen, P., West, S.G., & Aiken, L.S. (2003). *Applied multiple regression correlation analysis for the behavioral sciences* (3rd ed.). New York, NY: Routledge.

*Collins, C.J., & Smith, K.G. (2006). Knowledge exchange and combination: The role of human resource practices in the performance of high-technology firms. *Academy of Management Journal, 49*(3), 544–560. doi:10.5465/AMJ.2006.21794671

Cooper, H. (2010). *Research synthesis and meta-analysis: Applied social research methods series* (4th ed., Vol. 2). Thousand Oaks, CA: Sage.

DeChurch, L.A., & Mesmer-Magnus, J. R. (2010). The cognitive underpinnings of effective teamwork: A meta-analysis. *Journal of Applied Psychology, 95*(1), 32–53. doi:10.1037/a0017328

De Dreu, C.K.W., & Beersma, B. (2010). Team confidence, motivated information processing, and dynamic group decision making. *European Journal of Social Psychology, 40*(7), 1110–1119. doi:10.1002/ejsp.763

Gall, M.D., Gall, J.P., & Borg, W.R. (2010). *Applying educational research: How to read, do, and use research to solve problems of practice* (6th ed.). Boston, MA: Pearson.

*Garg, M. (2010). Impact of enterprise resource planning on organizational productivity in an information technology organization (Walden University). *ProQuest Dissertations and Thesis*, 243. Retrieved from http://search.proquest.com/docview/305221096?accountid=7113

*Gino, F., Argote, L., Miron-Spektor, E., & Todorova, G. (2010). First, get your feet wet: The effects of learning from direct and indirect experience on team creativity. *Organizational Behavior and Human Decision Processes, 11*(2), 102–115. doi:10.1016/j.obhdp.2009.11.002

Hinsz, V.B., & Ladbury, J.L. (2012). Combinations of contributions for sharing cognitions in teams. In E. Salas, S.M. Fiore, & M. P. Letsky (Eds.), *Theories of team cognition: Cross-disciplinary perspectives* (pp. 245–270). New York, NY: Routledge.

Hinsz, V.B., Tindale, S.R., & Vollrath, D.A. (1997). The emerging conceptualization of groups as information processors. *Psychological Bulletin, 121*, 43–64. doi:10.1037/0033-3909.121.1.43

Hollingshead, A.B. (1996). The rank order effect in group decision making. *Organizational Behavior and Human Decision Processes, 68*, 181–193. doi:10.1006/obhd.1996.0098

*Johnson, T.E., & Lee, Y. (2008). The relationship between shared mental models and task performance in an online team-based learning environment. *Performance Improvement Quarterly, 21*(3), 97–112. doi:10.1002/piq.20033

Johnson, T.E., & O'Connor, D.L. (2008). Measuring team shared understanding using the analysis-constructed shared mental model methodology. *Performance Improvement Quarterly, 21*(3), 113–134. doi:10.1022/piq.20034

Kirkman, B.L., Tesluk, P.E., & Rosen, B. (2001). Assessing the incremental validity of team consensus ratings over aggregation of individual-level data in predicting team effectiveness. *Personnel Psychology, 54*(3), 645–667. Retrieved from onlinelibrary.wiley.com/journal/10.111/(ISSN)1744–6570

Klimoski, R., & Mohammed, S. (1994). Team mental model: Construct or metaphor? *Journal of Management, 20*, 403–437. doi:10.1177/014920639402000206

*Kontoghiorghes, C., Awbrey, S.M., & Feurig, P.L. (2005). Examining the relationship between learning organization characteristics and change adaptation, innovation, and organizational performance. *Human Resource Development Quarterly, 16*(2), 185–212. doi:0.1002/hrdq.1133

Kozlowski, S.W.J., & Ilgen, D.R. (2006). Enhancing the effectiveness of work groups and teams. *Psychological Science in the Public Interest, 7*(3), 77–124. doi:10.111/j.1529.1006.2006.00030.x

Leonard, D., & Swap, W. (1999). *When sparks fly: Igniting creativity in groups*. Boston, MA: Harvard Business School Press.

*Liang, D.W., Moreland, R., & Argote, L. (1995). Group versus individual training and group performance: The mediating role of transactive memory. *Personality and Social Psychology Bulletin, 21*(4), 384–393. doi:10.1177/0146167295214009

*Lim, B.-C., & Klein, K.J. (2006). Team mental models and team performance: A field study of the effects of team mental model similarity and accuracy. *Journal of Organizational Behaviour, 27*, 403–418. doi:10.1002/job387

Lipsey, M.W., & Wilson, D.B. (2001). *Practical meta-analysis*. Thousand Oaks, CA: Sage.

*Michinov, N., & Michinov, E. (2009). Investigating the relationship between transactive memory and performance in collaborative learning. *Learning and Instruction, 19*(1), 43–54. doi:10.1016/j.learninstruc.2008.01.003

*Michinov, E., Michinov, N., & Huguet, P. (2009). Effects of gender role and task content on performance in same-gender dyads: Transactive memory as a potential mediator. *European Journal of Psychology of Education, 24*(2), 155–168. Retrieved from www.springer.com/psychology/journal/10212

Mohammed, S., & Dumville, B.C. (2001). Team mental models in a team knowledge framework: Expanding theory and measurement across disciplinary boundaries. *Journal of Organizational Behavior, 22*(2), 89–106. Retrieved from http:www.onlinelibrary.wiley.com/journal/10.1002/(ISSN)1099-1379

Mohammed, S., Ferzandi, L., & Hamilton, K. (2010). Metaphor no more: A 15-year review of the team mental model construct. *Journal of Management, 36*(4), 876–910. doi:10.1177/014920630935680

*Onwuegbuzie, A.J., Collins, K.M.T., & Jiao, Q.G. (2009). Performance of cooperative learning groups in a postgraduate education research methodology course: The role of social interdependence. *Active Learning in Higher Education, 10*(3), 265–277. doi:10.1177/1469787409343190

*Pazos, P., Micari, M., & Light, G. (2010). Developing an instrument to characterise peer-led groups in collaborative learning environments: Assessing problem-solving approach and group interaction. *Assessment and Evaluation in Higher Education, 35*(2), 191–208. doi:10.1080/02602930802691572

*Pearsall, M.J., Ellis, A.P.J., & Stein, J.H. (2009). Coping with challenge and hindrance stressors in teams: Behavioral, cognitive, and affective outcomes. *Organizational Behavior and Human Decision Processes, 109*(1), 18–28. doi:10.1016/j.obhdp.2009.02.002

Stasser, G., & Titus, W. (1985). Pooling of unshared information in group decision making: Biased information sampling during discussion. *Journal of Personality and Social Psychology, 48*(6), 1467–1478. Retrieved from http://www.apa.org/pubs/journals/psp/index.aspx

Stasser, G., Vaughan, S.I., & Stewart, D.D. (2000). Pooling unshared information: The benefits of knowing how access to information is distributed among group members. *Organizational Behavior and Human Decision Processes, 82*, 102–116. doi:10.1006/obhd.2000.2890

Surowiecki, J. (2005). *The wisdom of crowds*. New York, NY: Anchor Books.

Tzeng, J.-Y. (2006). Developing and sharing team mental models in a profession-driven and value-laden organization. *Performance Improvement Quarterly, 19*(2), 155–172. doi:10.111/j.1937-8327.2006.tb00370.x

Wegner, D.M. (1986). Transactive memory: A contemporary analysis of the group mind. In G. Mullen & G. Goethals (Eds.), *Theories of group behavior* (pp. 185–208). New York, NY: Springer-Verlag.

*Weldy, T.G., & Gillis, W.E. (2010). The learning organization: Variations at different organizational levels. *Learning Organization, 17*(5), 455–470. doi:10.1108/09696471011059831

*Williams, E.A., Duray, R., & Reddy, V. (2006). Teamwork orientation, group cohesiveness, and student learning: A study of the use of teams in online distance education. *Journal of Management Education, 30*(4), 592–616. doi:10.1177/1052562905276740

Wittenbaum, G.M., Hubbell, A.P., & Zuckerman, C. (1999). Mutual enhancement: Toward an understanding of the collective preference for shared information. *Journal of Personality and Social Psychology, 77*(5), 967–978. Retrieved from http://www.apa.org/pubs/journals/psp/index.aspx

## JOHN R. TURNER

John R. Turner is a doctoral candidate at the University of North Texas in the applied technology and performance improvement program. He started his career in mechanical engineering, where he was employed for 15 years. After leaving the engineering service industry, he completed a second bachelor's degree in psychology from the University of Arkansas at Little Rock, followed by a master's degree in human resource development from the University of Texas at Tyler. He has published articles in *Performance Improvement* journal, *Journal of Knowledge Management*, and *International Journal of Technology, Knowledge, and Society*.
*E-mail:* jrthpt@gmail.com

## QI CHEN

Qi Chen, PhD, is with the University of North Texas. Her quantitative research interests are longitudinal and mediational data analysis using

multilevel models, structural equation models, and mixture models (e.g., misspecification in growth mixture models), as well as the application of these models in educational, policy, and family research (e.g., school-based prevention, teacher-student relationship, parenting and child achievement). Recent work has appeared in peer-reviewed journals, including *Structural Equation Modeling, Journal of Applied Developmental Psychology, The Elementary School Journal, Educational Evaluation and Policy Analysis, Developmental Psychology, Journal of Family Psychology,* and *Early Childhood Research Quarterly*.
*E-mail:* qi.chen@unt.edu

## SHELBY DANKS

Shelby Danks is a Journey to Excellence specialist at a large health care system in north Texas. Her research interests include emerging measures of organizational performance and effectiveness.
*E-mail:* shelbydanks@gmail.com

## Appendix: Study Quality Evaluation Questions from Gall, Gall, and Borg (2010)

### 1. Introduction

| | |
|---|---|
| Q 1. | Is the literature review section of the report sufficiently comprehensive, and does it include studies that you know to be relevant to the problem? |
| Q 1.1 | Is each variable in the study clearly defined? |
| Q 1.2 | Is the measure of each variable consistent with how the variable was defined? |
| Q 1.3 | Are the research hypotheses, questions, or objectives explicitly stated, and if so, are they clear? |
| Q 1.4 | Do the researchers make a convincing case that a research hypothesis, question, or objective was important to study? |

### 2. Method Section

| | |
|---|---|
| Q 2. | Did the sampling procedures produce a sample that is representative of an identifiable population, or generalizable to your local population? |
| Q 2.1 | Did the researchers form subgroups to increase understanding of the phenomena being studied? |
| Q 2.2 | Is each measure appropriate for the sample? |
| Q 2.3 | Is each measure in the study sufficiently valid for its intended purpose? |
| Q 2.4 | Is each measure in the study sufficiently reliable for its intended purpose? |
| Q 2.5 | Were the research procedures appropriate and clearly stated so that others could replicate them if they wished? |

### 3. Results Section

| | |
|---|---|
| Q 3. | Were appropriate statistical techniques used, and were they used correctly? |
| Q 3.1 | Was the practical significance of statistical results considered? |

### 4. Discussion Section

| | |
|---|---|
| Q 4. | Do the results of the data analyses support what the researchers conclude are the findings of the study? |
| Q 4.1 | Did the researchers provide reasonable explanations of the findings? |
| Q 4.2 | Did the researchers relate the findings to a particular theory or body of related research? |
| Q 4.3 | Did the researchers draw sound implications for practice from their findings? |
| Q 4.4 | Did the researchers suggest further research to build on their results, or to answer questions that were raised by their findings? |

Scoring for each item was based on a scale from 0 = No, 1 = Somewhat, to 2 = Yes.