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Clarifying the Role of Self-Efficacy and Metacognition as Indicators of Learning: Construct Development and Test

Trevor T. Moores
University of Nevada, Las Vegas

Jerry Cha-Jan Chang
University of Nevada, Las Vegas, jchang@unlv.nevada.edu

Deborah K. Smith
University of Nevada, Las Vegas

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University of Nevada, Las Vegas

Abstract

We propose extending our understanding of self-efficacy by comparing self-efficacy with a related construct called metacognition. Metacognition involves the monitoring and control of one's thought processes and is often related, as is self-efficacy, to performance on a task. We develop an instrument that attempts to measure both self-efficacy and metacognition with respect to one's performance on a test covering declarative and procedural knowledge (knowing that, and knowing how) of DFDs and ERDs. With data collected from a sample of 124 students, we use partial least squares (PLS) to show that self-efficacy and metacognition are distinct yet related constructs. While self-efficacy is a predictor of both declarative and procedural knowledge, metacognition is only related to procedural knowledge. We discuss the implications of these results and suggest further research is needed to compare and contrast the role of these constructs in assessing learning outcomes.

ACM Categories: K.3.2, H.2.1.

Keywords: Data Flow Diagrams (DFDs), Declarative Knowledge, Entity-Relationship Diagrams (ERDs), Metacognition, Procedural Knowledge, Self-Efficacy.

Introduction

Self-efficacy is a belief in one's ability to organize and execute courses of action required to attain some designated level of performance (Bandura, 1986; 1997), and is used to predict an individual's ability or desire to perform a task (Gist & Mitchell, 1992; Stajkovic & Luthans, 1998). This construct has been adopted by MIS research as a potential measure of users' ability or desire to use information technology, with the computer self-efficacy (CSE) construct used as a predictor of an individual's level of self-reported computer use (Compeau & Higgins, 1995a; 1995b; Johnson & Marakas, 2000; Marakas et al., 1998). Research has shown a positive relationship between self-efficacy and learning performance in computer training, specifically declarative knowledge (Gist et al., 1989; Martocchio & Hertenstein, 2003). This paper seeks to extend our understanding of the value of self-efficacy in training programs by comparing self-efficacy to a related construct called metacognition.

Metacognition is the "executive" process that monitors and controls one's cognitive processes, and is often defined in terms of metacognitive knowledge and metacognitive experiences (Flavell, 1979; 1987). Metacognitive knowledge includes knowledge of oneself, the task at hand, and the strategy for successfully completing the required task. For instance, a student who knows they are better at multiple-choice than long-answer questions (oneself) will decide that for an upcoming test (the task) they will answer the multiple-choice questions first in order to leave more time for the long-answer questions (the strategy). Metacognitive experiences provide the feedback to the behavioral control process by monitoring the implemented strategy, determining whether it is being successful, and assessing the outcomes. In short, metacognition provides one with "… the ability to know how well one is performing, when one is likely to be accurate in judgment, and when one is likely to be in error" (Kruger & Dunning, 1999, p. 1121).

Metacognition is similar to self-efficacy in that metacognitive self-assessments have been related to an individual's ability to perform a task, solve problems, or acquire new skills (Cuevas et al., 2004; Davidson et al., 1994; Hartman, 2001; Paris & Winograd, 1990). Improving the accuracy of metacognitive judgments has also been found to lead to an improvement in learning or task performance (Kruger & Dunning, 1999). The similarity in the dependent variable often results in measurement instruments that use very similar items. In particular, self-efficacy and metacognition are both measured with respect to some level of achievement in performing a task. However, there are also three key differences between self-efficacy and metacognition.

First, according to Bandura's general model of Social Cognitive Theory, self-efficacy is a determinant of behavior and indirectly affects performance. Given the difficulty in measuring the behavior that goes into accomplishing a task it is no surprise to find that most studies choose to relate self-efficacy directly to (measurable) performance. Metacognition, on the other hand, has a complex relationship with both behavior and performance, initiating the (problem-solving) behavior, monitoring performance, and changing behavior if things are not going as expected. This difference makes metacognition useful in enhancing end-user training since the dependent variable of most concern is not only whether someone will use a computer (behavior), but whether employees can use a computer to become more effective at accomplishing job related tasks (performance). In order to go beyond an understanding of behavior, therefore, we need to examine the relationship between behavior and attained levels of performance. It is the role of metacognition to provide the necessary feedback loop between performance and behavior by monitoring levels of performance and controlling subsequent behavior (Nelson & Narens, 1996).

Second, metacognition is generally considered to be a unidimensional construct, and is often measured as a declaration of confidence or certainty in the accuracy or adequacy of performance (McGuire & Maki, 2001; Nelson et al., 2004), as a judgment of learning (Kelemen, 2000), or as a feeling of knowing (Metcalfe et al., 1993) either just before or just after the behavior of interest. As such, the method of measurement is generally a Likert-type confidence scale (Schwartz, 1994). On the other hand, self-efficacy is a three-dimensional construct including level, strength, and generality, with measurement usually focusing on only one or two of the dimensions (e.g., strength). Self-efficacy instruments are normally developed as a related set of items that increase or decrease in task difficulty (Compeau & Higgins, 1995a; Johnson & Marakas, 2000).

Third, while self-efficacy is usually defined as positively correlated with behavior and performance, metacognitive judgments are often at odds with objective measures of learning or task performance. This results from a phenomenon known as metacognitive miscalibration (MM) where an individual misjudges his/her level of proficiency by being either overconfident or under-confident and can lead to premature termination of task effort. For instance, a student may stop studying for a test based on erroneous judgment of being good enough already (overconfident), or simply expecting to fail (under-confident). Some hypothesized reasons for MM include cue familiarity (Metcalfe et al. 1993) and the above average effect (Alicke et al., 1995; Dunning et al., 1989). Put simply, familiarity results in over-confidence, while few people are willing to admit they are "below average." Whether inaccurate beliefs about one's self-efficacy poses a concern continues to generate debate (e.g., Vancouver et al., 2002; Bandura & Locke, 2003).

In summary, self-efficacy and metacognition are similar to the extent that they have been related to behavior and performance, and consequently studies often use items that appear to be very similar; they differ in terms of their theoretical relationship to behavior and performance, the method of measurement, and the implications of misjudgment.

Research Model

We investigate the relationship between self-efficacy (SE) and metacognition (META) by relating both constructs to performance in a specific cognitive task. In this case, the task of taking a test related to knowledge of DFDs and ERDs. Self-efficacy is defined here in terms of a belief in one's ability to organize and execute courses of action required to do well in the above mentioned task. Metacognition is defined here in terms of a judgment of one's likely level of performance in that task. Performance is defined in terms of declarative (DECL) and procedural (PROC) knowledge, since both types of knowledge are typically being taught when someone learns a new technique (e.g., see Newell, 1990). The theoretical model is given in Figure 1.

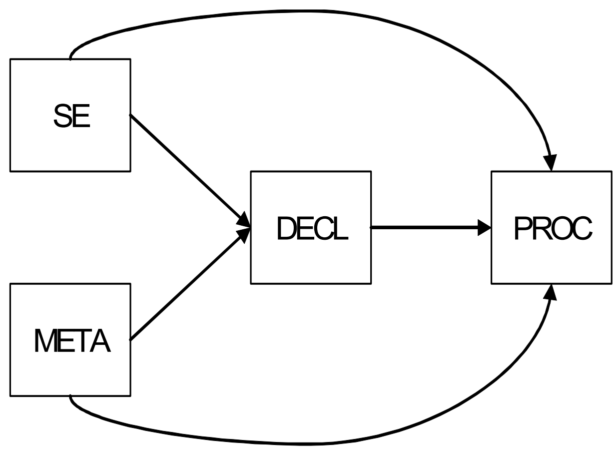


Figure 1. Research Model

Declarative knowledge is factual knowledge (i.e., “Knowing that …”), while procedural knowledge is knowledge of how to do something (i.e., “Knowing how …”). For instance, declarative knowledge of DFDs and ERDs would include the symbols used in such diagrams, while procedural knowledge involves the ability to produce a DFD or ERD from a given problem statement. The importance of understanding the distinction between these two types of knowledge is that when learning a cognitive skill it has been suggested that a learner must compile declarative knowledge into a procedural form, which then undergoes a process of refinement in terms of expertise and raw speed (Anderson, 1982; 1993). We represent this relationship in our theoretical model as a path from declarative to procedural knowledge.

Recent studies have found a positive relationship between self-efficacy and declarative knowledge (Martocchio & Hertenstein, 2003; Yi & Davis, 2003). Similarly, there is also evidence that supports a positive relationship between metacognition and declarative knowledge (Schmidt & Ford, 2003). There has been little or no research, however, on the relation between self-efficacy or metacognition and procedural knowledge. We propose taking the next logical step and relating self-efficacy and metacognition to procedural knowledge. By analyzing both types of knowledge we can determine whether self-efficacy or metacognition is related to the (earlier) process of acquiring declarative knowledge, or the (later) process of demonstrating procedural knowledge. Given the behavioral aspects of procedural knowledge we might anticipate self-efficacy to be related to procedural as well as declarative knowledge. Given the potential for metacognitive miscalibration, however, it is unclear at this point whether metacognition will be related to either knowledge type.

Method

We developed twenty items that assessed students' self-efficacy on declarative and procedural aspects of ERDs and DFDs (five items each) in decreasing order of task difficulty from “with absolutely no help,” to “with help from the instructor.” Task difficulty is defined here in terms of levels of help because of the complex nature of the task under study – taking a test – and because respondents would recognize levels of help as varying the degree of difficulty in completing the task. To be comprehensive and compatible to Bandura's conceptualization we used a “yes/no” with 10 point confidence scale for each item to capture both magnitude and strength(Yi & Davis, 2003; Ryan et al., 2000; Compeau & Higgins, 1995a).

Since metacognition is thinking about thinking, the items are developed in terms of an individual's *thoughts* regarding ability and performance. Affect is minimized in metacognitive items; the word “think” is used while the terms “feel” and “believe” are avoided. When assessing judgments of learning, a Likert-type confidence scale is often used asking how well the respondent thinks they can or did perform a particular task (Schwartz, 1994). A previous pilot study (Smith et al., 2003) showed that items related to exam grades (A to F) were relatively weak – perhaps because of expectations of grade inflation – and so students were asked to predict their exam performance in terms of a numeric score (0 to 100%). The self-efficacy and metacognitive items used in the study are given in Table 1.

A test was designed to collect data on declarative and procedural knowledge. Declarative knowledge is measured by 30 multiple-choice questions on DFDs and ERDs (15 on each technique). Procedural knowledge is measured in terms of producing a DFD and an ERD from given problem statements. The score in each section represents the performance score. One of the researchers was also the instructor that graded the test.

Data collection was conducted with MIS students in week 8 of a 16-week core IS Analysis and Design course at a large Southwestern US University. An instrument containing both self-efficacy and metacognitive measures with separate sections for

Metacognition (META) (a judgment of one's likely level of performance in a test)	
Declarative Items	
M-DDFD	What score would you expect on an exam covering only **declarative knowledge** of **DFDs** if you took the test today? (1-100)
M-DERD	What score would you expect on an exam covering only **declarative knowledge** of **ERDs** if you took the test today? (1-100)
Procedural Items	
M-PDFD	What score would you expect on an exam covering only **procedural knowledge** of **DFDs** if you took the test today? (1-100)
M-PERD	What score would you expect on an exam covering only **procedural knowledge** of **ERDs** if you took the test today? (1-100)
Self-Efficacy (SE) (a belief in one's ability to organize and execute courses of action required to do well in a test)	
Declarative Items	
I could explain **DFD** definitions and concepts …	
S-DDFD1	… with absolutely no help
S-DDFD2	… with reference to my class notes
S-DDFD3	… with reference to my notes and textbook
S-DDFD4	… with some help from a classmate
S-DDFD5	… with some help from the instructor
I could explain **ERD** definitions and concepts …	
S-DERD1	… with absolutely no help
S-DERD2	… with reference to my class notes
S-DERD3	… with reference to my notes and textbook
S-DERD4	… with some help from a classmate
S-DERD5	… with some help from the instructor
Procedural Items	
I could create a **DFD** from a problem description …	
S-PDFD1	… with absolutely no help
S-PDFD2	… with reference to my class notes
S-PDFD3	… with reference to my notes and textbook
S-PDFD4	… with some help from a classmate
S-PDFD5	… with some help from the instructor
I could create an **ERD** from a problem description …	
S-PERD1	… with absolutely no help
S-PERD2	… with reference to my class notes
S-PERD3	… with reference to my notes and textbook
S-PERD4	… with some help from a classmate
S-PERD5	… with some help from the instructor
Performance (a test of declarative and procedural knowledge of DFDs and ERDs)	
Declarative Items **(DECL)**	
P-DDFD	Multiple-choice questions (max. score=15)
P-DERD	Multiple-choice questions (max. score=15)
Procedural Items **(PROC)**	
P-DDFD	Producing a DFD from a given problem statement (max. score=25)
P-DERD	Producing an ERD from a given problem statement (max. score=25)

Table 1. Metacognitive and Self-Efficacy Items Used in the Study

declarative knowledge and procedural knowledge was administered to the students in the class session immediately prior to the test. The instrument included a definition of declarative knowledge as factual knowledge ("Knowing that …"), and a definition of procedural knowledge as knowing how to do something ("Knowing how …"). In total 138 responses were received, of which 14 were incomplete, resulting in a final sample of 124 usable responses.

Results

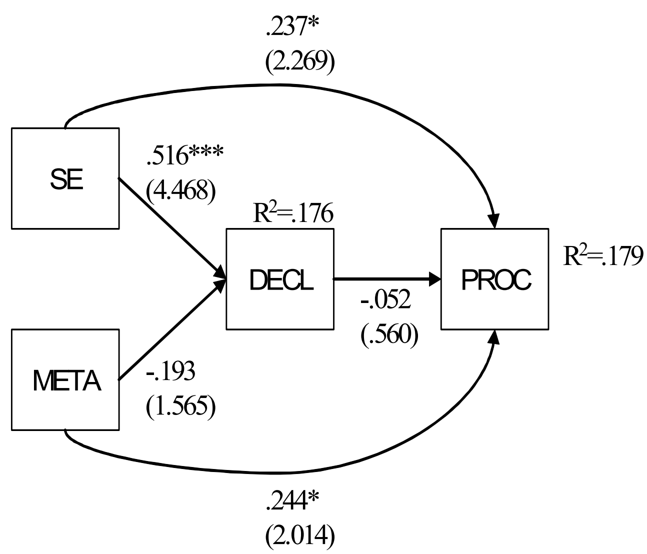
Data analysis is conducted using Partial Least Square (PLS) Graph Version 3.00 Build 1126. PLS is suitable because the main focus of the study is to examine the predictive validity of self-efficacy and metacognition on performance. In addition, PLS does not require normal distribution for the manifest variables. Kolmogorov-Smirnov's tests of normality indicate that none of the measured items are normally distributed ($p<0.01$). PLS also allows testing of the measurement and structural model simultaneously. We define all items as reflective indicators for their respective construct and test the proposed research model. Measurement properties are examined for internal consistency, reliability, and convergent and discriminant validity.

The results (see Table 2) suggest that all constructs have composite reliability well above the 0.7 threshold and average variances extracted (AVE) above the required 0.50 threshold, demonstrating good reliability (Chin, 1998). The item loadings are all high (>0.7) and significant, determined by the t-statistics obtained from bootstrapping with 100 resamples. The only exception is the performance measure of declarative DFD (loading=0.624). However, the t-statistic is significant ($p<0.001$). Since there are only two manifest variables for declarative knowledge we retain the item for further analysis. Discriminant validity in PLS is determined by comparing the square root of the AVE for each construct with latent construct correlations. Table 3 shows that all latent construct correlations are much lower.[1] These results indicate good convergent and discriminant validity (Chin, 1998).

The structural model is assessed by examining path coefficients and their significance level. Figure 2 shows the results of structural analysis with t-statistics obtained from bootstrapping (100 resamples). The results indicate that self-efficacy has significant effects on both declarative and procedural knowledge, while metacognition affects only procedural knowledge. The path from declarative knowledge to procedural knowledge is not significant. The R^2 for both declarative and procedural knowledge is similar, indicating that self-efficacy and metacognition combine to explain approximately the same amount of variance in each variable. Furthermore, the path coefficients for self-efficacy and metacognition to procedural knowledge are similar, suggesting they play equal roles in explaining the variance in procedural knowledge.

Discussion

The results of this study suggest that self-efficacy and metacognition are distinct but related constructs. This has important implications for researchers of either concept since items must be carefully designed to measure the intended construct. We caution future research to clearly differentiate scales that assess confidence in performing a task with varying level of difficulty (self-efficacy) and scales that measure expected proficiency of task performance (metacognition). Although we followed previous research in using a fairly simple measure of metacognition, the complexity of this concept, involving knowledge and experience, may warrant further research into its measurement.



NOTE: t-Tests shown in parentheses. * $p<0.05$ ** $p<0.01$ *** $p<0.001$

Figure 2. Results of the PLS Analysis

The non-significant effect of declarative knowledge on procedural knowledge could be due to the fact that respondents are still novices in the subject area and the transition from mastering the underlying concepts to applying the technique is incomplete.

[1] The Variance Inflation Factor (VIF) for SE and META when used to predict performance is 1.707, which is well below the threshold of VIF<10 (Hair et al., 1998) and indicates there are no multicollinearity problems with the two measures.

Var.	Weight	Loading	t-Stat
Metacognition (META) (Composite Reliability = 0.976, AVE = 0.911)			
M-DDFD	0.263	0.946	38.849
M-DERD	0.270	0.959	56.366
M-PDFD	0.252	0.959	51.250
M-PERD	0.262	0.955	46.823
Self-Efficacy (SE) – Strength (Composite Reliability = 0.983, AVE = 0.743)			
S-DDFD1	0.046	0.732	16.884
S-DDFD2	0.061	0.893	40.520
S-DDFD3	0.063	0.875	20.619
S-DDFD4	0.055	0.848	17.696
S-DDFD5	0.067	0.794	17.161
S-DERD1	0.045	0.762	19.923
S-DERD2	0.058	0.895	41.860
S-DERD3	0.061	0.921	59.484
S-DERD4	0.053	0.911	32.683
S-DERD5	0.065	0.848	22.690
S-PDFD1	0.045	0.753	16.204
S-PDFD2	0.059	0.910	46.050
S-PDFD3	0.064	0.926	63.143
S-PDFD4	0.056	0.895	32.606
S-PDFD5	0.068	0.842	22.759
S-PERD1	0.049	0.798	21.715
S-PERD2	0.062	0.922	52.148
S-PERD3	0.062	0.929	64.203
S-PERD4	0.053	0.885	31.983
S-PERD5	0.066	0.849	26.169
Performance - Declarative (DECL) (Composite Reliability = 0.788, AVE = 0.661)			
P-DDFD	0.283	0.624	4.571
P-DERD	0.853	0.966	28.162
Performance - Procedural (PROC) (Composite Reliability = 0.872, AVE = 0.774)			
P-PDFD	0.697	0.937	34.229
P-PERD	0.424	0.819	15.355

NOTE: All t-Stats are significant at $p<0.001$

Table 2. Factor Loadings for Constructs

A test of this relationship at the end of the course may show a different result. A difference in the complexity of the task may also be a factor. The measure of declarative knowledge consisted of 30 multiple choice questions that students can typically answer in less than 10 minutes. Multiple-choice questions also allow students the opportunity to see potential answers, allowing them to 'hit upon' the right answer by eliminating those they know to be wrong. The procedural question is more cognitively demanding: there are no clues, no process of elimination, and students typically spend most of the test time answering the procedural questions. Given this difference in complexity, it is perhaps not surprising that one's performance in answering multiple choice questions does not relate to one's performance in producing a DFD or ERD.

This difference in complexity may also explain the different relationships found between self-efficacy, metacognition, and the two knowledge types. As expected, self-efficacy is found to have a strong impact on declarative knowledge, suggesting that for simple tasks self-efficacy can be a good predictor of performance. As the cognitive demands of the task increases, however, the predictive power of self-efficacy weakens and the role of metacognition becomes more important. The moderating effect of task complexity on the relationship between self-efficacy and performance has been noted previously (e.g., Gist & Mitchell, 1992). It is also possible that task complexity moderates the relationship between metacognition and performance. An interesting area of further research would be to uncover the relationship between self-efficacy, metacognition and performance for progressively more complex tasks.

In order to promote higher levels of proficiency in using technology, therefore, these results suggest we begin by promoting levels of self-efficacy to ensure technology adoption. To progress from novice to expert user, we must then pay attention to promoting the feedback loop of metacognition that controls behavior in response to monitoring levels of performance. The relationship between self-efficacy, metacognition, and performance would undoubtedly continue to interact. Metacognitive judgments of performance – whether miscalibrated or not – would then control subsequent behavior, impacting on one's sense of self-efficacy, and promoting the next round of behavior that would then be judged again by the metacognitive processes. The impact of metacognitive miscalibration, and whether inaccuracy in one's self-efficacy beliefs aids or subverts levels of performance, remains an open question.

Conclusions

We proposed extending our understanding of self-efficacy as an indicator of performance by comparing and contrasting self-efficacy to metacognition. We extended previous studies by defining performance in terms of both declarative and procedural knowledge. We showed that self-efficacy and metacognition are distinct constructs, with self-efficacy significantly related to both types of knowledge, while metacognition is significantly related to procedural knowledge. We speculated that the difference in task complexity may explain some of these results.

Based on these results we suggest that further research is needed to clarify the relationship between self-efficacy, metacognition, and the types of knowledge being imparted during training programs, especially for tasks that vary in complexity. This has important implications for any organization seeking to promote greater proficiency in the use of information technology. To design training programs that aim to develop expert levels of performance in complex tasks, an understanding of both self-efficacy and metacognition is required.

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About the Authors

Trevor T. Moores (PhD, University of Aston, UK) is Assistant Professor of MIS at the University of Nevada, Las Vegas. His research interests include IT ethics, software piracy, software measurement, and self-efficacy/metacognition. He has published in *Communications of the ACM, European Journal of Information Systems, IEEE Transactions on Knowledge and Data Engineering, Information & Management, MIS Quarterly*, and others. Email: trevor.moores@unlv.edu.

Jerry Cha-Jan Chang (PhD, University of Pittsburgh) is Assistant Professor of MIS at the University of Nevada, Las Vegas. His research interests include instrument development, IS performance measurement, self-efficacy, software piracy, use and impact of IT, and cultural aspects of IS. He has published in *MIS Quarterly, Journal of MIS, Information & Management, Communications of the ACM,* and others. Email: jchang@unlv.nevada.edu.

Deborah K. Smith (PhD, Texas A&M University) is Assistant Professor of MIS at the University of Nevada, Las Vegas. Her research interests include creativity, cognition, metacognition, and IS education. She has published in *Communications of the ACM, Journal of CIS*, and other leading MIS conferences. Email: deborah.smith@ccmil.nevada.edu.