



The interplay between cognitive and motivational variables in a supportive online learning system for secondary physical education

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ABSTRACT

A path model was used to test the unique and interactive effects of cognitive and motivational variables when learning in a supportive online learning system, Collaborative Inquiry System (CIS). In this student-centered learning environment, students interact with computer simulations and are assisted by online scaffolds intended to help them learn complex scientific concepts. The present study also explored the relationships between students' motivational, cognitive, and metacognitive strategy use and online performance. In total, 178 tenth-grade students participated in the study. The statistical analyses revealed that students' learning goals and cognitive preferences predicted metacognitive strategy use and later influenced their performance. Prior knowledge is a predictor of neither metacognitive strategy use nor learning goals and need for cognition, but is nevertheless an important determinant of online performance. Discussions on how to accommodate the different needs of students with varying levels of prior knowledge, goal orientation, and cognitive preference in a supportive learning system are provided based on the results.

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1. Introduction

An historic balance point in the study of online learning is how unique contexts influence what are often considered universal human characteristics. Debates among researchers have resulted in the following demands: greater empirical rigor; improved ways of generalizing and broadening the utility of research findings (Jacobson, 2008); greater sensitivity to the uniqueness and individuality of online learners; and a bolstering of research authenticity (Whipp & Chiarelli, 2004). In the present study, we used a data-driven approach to examine the interplay between the cognitive and motivational variables that influence students' learning outcomes in an online learning environment. Our intent was to reconcile some of the assertions underlying discussions of the universality of human cognition and motivation on the one hand, and the uniqueness of online contexts on the other.

2. Issues in online learning contexts

Online learning offers many distinctive features and has been recognized by many educational researchers and practitioners as an optimal approach to teaching and learning (Crook, 1994; Spiro, Feltovich, Jacobson, & Coulson, 1992). This type of learning context provides a media-rich environment with access to vast resources and allows a more flexible approach to instruction (Khalifa & Lam, 2002). Consequently, online learning methods have been shown to support student-centered pedagogies and to engage students in active learning (Jacobson, 2008).

Despite online learning's capacity to empower teaching and learning, empirical evidence indicates that learners with different levels of prior knowledge benefit differently from online learning. Such variation also results in different preferences for using learning strategies and navigational control (Ghinea & Chen, 2003; Mitchell, Chen, & Macredie, 2005). There is no question about the utility of prior knowledge in predicting student performance. However, learning cannot be reduced to a simple cause and effect relationship; instead, it must be seen as the result of systematic interactions of factors, including the background that each student brings to the instructional context. It is, therefore,

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essential to investigate antecedents to online learning in order to help designers understand the needs of distinct learners. In this paper, a framework is presented to illustrate the effects of interaction between online learning and learners' variables in order to design efficient, effective and satisfying systems that accommodate different types of learners.

3. Learner variables

In previous studies (e.g., Ben-David & Zohar, 2009; Jiang, Elen, & Clarebout, 2009; Johnson, 2005; Jones, 2008), researchers examined the prerequisite factors important in predicting student performance. Achievement goal theory, need for cognition, and metacognition were of particular interest to the current study. This study focused on variables that had not been rigorously examined in the context of online learning yet had been shown to be influential in adolescents' motivation, including performance goals, learning goals, need for cognition and metacognitive strategy use. The relationship between these sets of variables as demonstrated in multiple studies (Eccles & Roeser, 2009; Patrick, Ryan, & Kaplan, 2007) is summarized in the following sections.

3.1. Achievement goal orientation

Students bring to learning contexts personal characteristics, such as individual goals and varying degrees of motivation. Achievement goal orientations are normally divided into three types: learning (or mastery), performance-approach, and performance-avoidance (Elliott & Church, 1997; Maehr & Midgley, 1996). Learning goals characterize individual's inclination to know and understand the content or master the skills out of own desire (Ames, 1992; Kaplan & Maehr, 2007). Performance-approach goals characterize individual's inclination to outperform others or look good in the face of external social pressure and comparisons (Church, Elliot, & Gable, 2001; Greene & Miller, 1996). Performance-avoidance goals characterize individual's inclination to elude work or performance so as to avoid embarrassment or appearing incompetent (Elliot & Harackiewicz, 1996). Learning goals are seen as productive and positive orientations that motivate all students, while performance-approach and performance-avoidance goals have mixed consequences (Midgley, Kaplan, & Middleton, 2001; Pintrich, Conley, & Kempler, 2003).

These goal orientations have been of interest to educational psychologists and researchers because they are believed to influence an individual's approach to learning and achievement as well as task choice, attitude, persistence, engagement, and motivation (Church et al., 2001; Deci & Ryan, 2000; Dweck & Leggett, 1988; Elliott & Church, 1997; Miller, Behrens, Greene, & Newman, 1993). Miller, Greene, Montalvo, Ravindran, and Nichols (1996) found that high school math students with strong learning goals report greater use of self-regulatory activities and meaningful or deep cognitive strategies than do students with performance goals. Greene and Miller (1996) replicated these findings with university students. The majority of studies investigating the effects of achievement goals on student performance have been largely focused on traditional classroom situations; however, achievement goals have not been sufficiently taken into account in the context of online learning environments (Aleven, Stahl, Schworm, Fischer, & Wallace, 2003). To benefit fully from online learning environments where learners are exposed to vast resources and a multitude of information, students must use appropriate strategies (i.e., monitoring comprehension) and deep cognitive processing (i.e., recalling prior knowledge). A number of studies have begun to examine the impact that students' goal orientations may have on taking an initiative to use help tools available within the online learning environment. While Ryan and Pintrich (1997) found seventh and eighth graders with learning goals were more likely to seek information or help in improving and refining their skills, a negative relationship between learning goals and learning behavior was found in the context of online learning where students were unlikely to use help tools (Clarebout & Elen, 2009; Huet, Escribe, Dupeyrat, & Sakdavong, 2011). Reports on the role of achievement goals in online learning environments have been shown to be incongruent to those of the traditional classroom in, for instance, the adoption and frequency of tool use (Jiang et al., 2009). It is plausible that a learner's goal orientation will influence his or her choice of learning strategies. Therefore, future research should examine the effects of integrating other learner variables, such as cognitive preferences or use of learning strategies, so that a more inclusive conclusion can be reached (Jiang et al., 2009).

3.2. Need for cognition (cognitive preference)

Just as achievement goals play a role in student motivation, so do students' cognitive preferences. Students' cognitive preferences influence their reception of and responses to teachers' and peers' messages regarding self-determination and goals (Reeve, 1996). One important preference is the need for cognition (NFC), which refers to individual preference for deep thinking or engagement in ill-structured problems (Evans, Kirby, & Fabrigar, 2003; Forsterlee & Ho, 1999). Students' NFC can influence both motivational and achievement outcomes (Greene, Miller, Crowson, Duke, & Akey, 2004; Wood & Bandura, 1989). Moreover, NFC may influence the way students interpret and respond to the learning contexts and goal structures; they are, therefore, important factors to consider with regard to motivation.

Several studies have demonstrated that high NFC individuals have the tendency to search, acquire, and process information (Cacioppo, Petty, Feinstein, & Jarvis, 1996). High NFC individuals seem to execute higher-order thinking activities and other types of cognitive tasks. Low NFC individuals, however, are more likely to depend on others' opinions and show less engagement in cognitive tasks (Kaynar & Amichai-Hamburger, 2008). Nussbaum (2005) found that individuals' levels of NFC greatly influence how they articulate and elaborate arguments. High NFC students tend to make more argumentative claims because they enjoy the thinking process, whereas low NFC students tend to provide less information, particularly less contradictory information (Kardash & Scholes, 1996). In addition, Coutinho, Wiemer-Hastings, Skowronski, and Britt (2005) found that when solving problems, high NFC students display greater motivation to seek out explanations for problems that they encounter.

Both goal orientation and cognitive preference are motivational responses to messages from the learning environment as perceived and interpreted by the student. Both can directly affect the depth of processing, test performance, and persistence at task (Vansteenkiste, Simons, Lens, Sheldon, & Deci, 2004). Yet this relationship has not been rigorously examined in the context of online learning. In addition, while attempts to understand students' goal orientations have opened up possibilities for studying the effects of motivational factors on learning, interactions with cognitive prerequisites and other motivational preferences within the context of e-learning should be emphasized so that we can better understand human behaviors in a goal-directed, web-based learning environment.

3.3. Prior knowledge

While many researchers have focused their attention on understanding student motivation and its effects on predicting or improving academic performance, students' prior knowledge should not be ignored. Motivation is related to task initiation, amount of effort expended, and persistence in completing the task (Pintrich & Schunk, 1996). Prior knowledge refers to the knowledge that students have prior to engaging in learning. According to constructivism, meaningful learning occurs when students build new information into their prior knowledge framework. Therefore, both motivation and prior knowledge are believed to affect actions and achievement.

A review of the existing literature indicates that prior knowledge is one of the most powerful determinants of students' success or failure in school (e.g., Ausubel, 1968; Dochy, 1992; Hailikari, Nevgi, & Komulainen, 2008; Tobias, 1994). Many studies have investigated the impact of prior knowledge, with almost all pointing out that prior knowledge is influential in online learning (Blake & Scanlon, 2007; Portier & Wagemans, 1995; Woloshyn, Paivio, & Pressley, 1994). Based on previous studies, Alevin et al. (2003) conclude that prior knowledge impacts learners' online behaviors and learning strategies. For example, students with a high level of prior knowledge perceive online tools as helpful to knowledge acquisition (Park, Lee, & Kim, 2009). A study that used computer simulations to model complex science learning found that the more successful students differ from the less successful students in that they rely more on prior knowledge and focus more on structure and less on manipulating parameters to make the model fit the given data (Sins, Savelsbergh, & van Joolingen, 2005). In other words, low prior knowledge students rely considerably on the given tools or tool outputs intended to promote learning and gain knowledge. A lack of prior knowledge prevents these students from acquiring new knowledge and causes an excess cognitive load on their working memory (Dochy, De Ridjet, & Dyck, 2002).

Researchers have also found that learning within a computer-assisted learning environment can be beneficial to those with low prior knowledge. An experimental study of second-graders' development of multiplication abilities found that students with low prior knowledge benefit more from computer-assisted activities than those with relatively high prior knowledge (Wang, Wang, Wang, & Huang, 2006). Similar research investigating college students found that students with low prior knowledge benefited most from online multimedia (Muller, Bewes, Sharma, & Reimann, 2008). Although numerous studies have investigated how students with varying levels interact and behave in online learning, only a few studies have emphasized the role that prior knowledge plays in strategy use and performance. For example, Mckeachie, Pintrich, and Lin (1985) stressed that although prior knowledge is important, it is not sufficient for effective learning. They also stated that, in order to do well in a learning program, a minimal level of basic skills is still needed. More research targeting different subject areas and different grade levels is needed before definitive conclusions can be drawn about the relationships between variable prior knowledge and other factors.

3.4. Metacognitive strategies

Metacognition refers to the knowledge and awareness of one's own cognitive activities and the ability to actively control and monitor those activities (Flavell, 1976). It requires deliberate conscious control of the skills and strategies required to complete a task as well as control and regulation of cognitive strategies (Flavell, 1987). Metacognition can be divided into metacognitive knowledge and metacognitive strategies. Metacognitive knowledge is the individual's declarative knowledge about the interactions between person, task and strategy characteristics (Flavell, 1979), whereas metacognitive strategies refer to the individual's procedural knowledge for regulating his or her own problem-solving and learning activities (Veenman, 2005). Some examples of metacognitive strategies are planning, setting goals, monitoring, evaluating, and reflecting. Smidt and Hegelheimer (2004) interviewed high-, middle-, or low-performing adult learners about their online learning strategies and discovered that only advanced learners used metacognitive strategies (along with cognitive ones). Intermediate- and lower-level students relied on cognitive strategies alone, suggesting that advanced metacognitive abilities may be either associated with or requisite to effective online learning. It is assumed that students who have, or develop, metacognitive strategies tend to perform more successfully than those who do not. However, the extent to whether the use of metacognitive strategies mediate or have a direct impact on online learning performance still requires further investigation. Thus, we must clarify the extent to which learners must possess metacognitive strategies and require advance training or the extent to which they can develop the requisite skills needed to monitor their progress. In this study, we are specifically interested in students' uses of metacognitive strategies to guide and direct their learning and problem-solving while interacting with different tasks within an interactive online learning environment.

The use of metacognitive strategies can help learners assess their learning outcomes in a more realistic way, that is, one that allows their self-assessment to be more accurate. However, past studies have shown that learners often do not demonstrate metacognitive processing. Moreover, the uses of metacognitive strategies for learning success have not proved unequivocally. For example, Elshout (1987) found that metacognitive strategies neither improved learning outcomes nor assisted the learners in producing an accurate self-assessment of their learning outcomes. Ge and Hardré (2010) found that students who were more metacognitive looked at the work of others and used it in reflecting on their own work. In the previous studies, however, the link between metacognitive strategies use and performance was not tested explicitly.

Understanding the role of metacognitive strategies in interactive learning environments is critical because it determines the necessity of including support for metacognitive strategies in achieving successful learning. Many studies have argued that metacognitive strategies use have no significant effect on domain knowledge gains but may enhance their quality (Molenaar, van Boxtel, & Slegers, 2010). As a consequence it is necessary to determine whether metacognitive strategies use have a direct impact on students' learning outcomes in online learning environments as well as on their relationships with untested variables.

4. The present study

To date, there is a paucity of motivational research examining multivariate relationships. There remains a need for more empirical, evidence-based research into how individual motivation (i.e., goal orientations, cognitive preferences) influences learning outcomes in online learning. Integrating theoretical research on cognition and motivation, this study validates an approach where three factors (prior knowledge, learning/performance goals, and need for cognition) contribute to online learning and one factor (metacognitive strategy use)

mediates the relationship between the aforementioned factors and performance. The research model (Fig. 1) is developed based on theories of cognition and motivation that examine the effects of online learning performance. In this study, motivation is complicated, integrated, and dynamic in human life and education. Motivation is also situated within the learning environment and controls individuals' actions and performance (Dai & Sternberg, 2004; Eccles & Roeser, 2009). Motivation can be iteratively affected by the learning environment and experiences, in turn having consequences on actions (Guay, Marsh, & Boivin, 2003; Linnenbrink & Pintrich, 2004). Therefore, motivation may not be sufficiently explained by a single-theory model but rather by the interactions of multiple constructs from different theoretical frameworks.

The present study is built on theoretical frameworks that address cognitive and motivational characteristics that are both internal processes and non-continuous behavioral indicators. If students are lacking one or more of these critical cognitive or motivational characteristics, they are in danger of being less than optimally motivated and engaged in the learning task (Pintrich et al., 2003; Pintrich & Schunk, 1996). Therefore, it is important that we identify and address students' cognitive motivational needs so that both teaching and learning are more effective (Hidi & Harackiewicz, 2000). Because online learning differs from traditional classroom learning, students are required to take initiative in acquiring new knowledge, applying effective learning strategies, and regulating learning behaviors so that successful online learning outcomes can be achieved. Although a vast number of studies have demonstrated the importance of motivation in online learning, only a few have included samples of high school students and have analyzed interactions and differences between cognitive and motivational factors. Even fewer have focused on the outcomes that these differences have on actual performance (as opposed to students' self-reported or perceived effects) as a result of online learning. To our knowledge, none examined differences between students' cognitive and motivational profiles and their effects on use of metacognitive strategies. Based on the theoretical and empirical literature, we investigated the following research questions:

- (1) How are cognitive factors related to students' use of metacognitive strategies and performance in online learning?
- (2) How are motivational factors related to students' uses of metacognitive strategies and performance in online learning?
- (3) Are these relationships mediated by use of metacognitive strategies?

5. Methodology

5.1. Participants

The study's participants included 178 tenth-grade students at a vocational high school in central Taiwan. The sample was composed of 167 males and 11 females with a mean age of 16.4 years old. Participation in the study was considered a course requirement, but the subjects' level of performance was not counted in determining course grades. Therefore, the participation outcomes were not constrained by extrinsic motivators such as grades or incentives.

5.2. Context of online learning system

To test our proposed model, we used an electronic-based Collaborative Inquiry System (CIS) that we previously built to support physics learning (Chen, Wu, & Lan, *in press*). The CIS database server was built using MS-SQL Server 2005, which serves as a rational database for storing users' personal and background information, courseware, simulations, inquiry prompts, and questionnaires, among others. We briefly describe below the purpose of each database within the system. The users' personal and background database records each student's learning process and test scores. The courseware database contains learning materials that are available to the students in the forms of multimedia. The simulations database contains computer simulation that is related to the science topic of projectile motion. The inquiry prompts database contains prompts that assist students to understand the computer simulation as well as engage in science inquiry

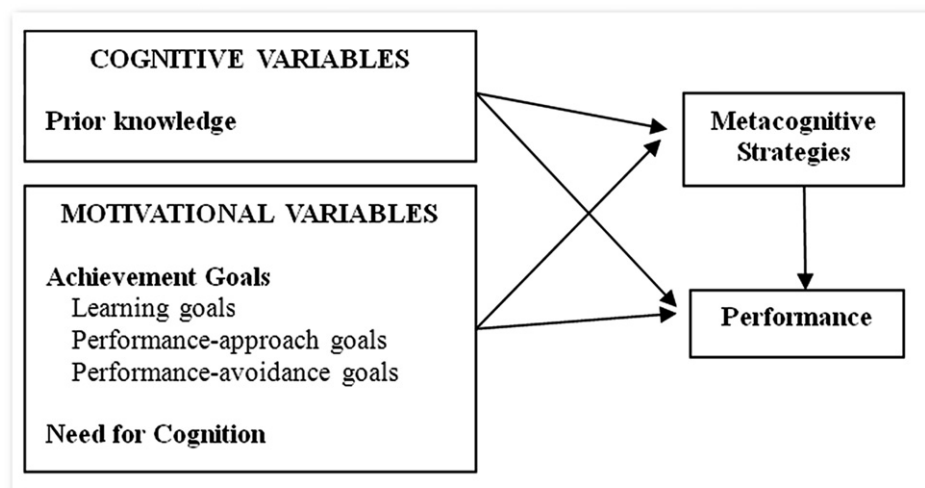


Fig. 1. Research model.

activities. Additional expert and peer feedback to the inquiry prompts are also made available for students to advance their learning in the system.

5.3. Measures

5.3.1. Prior knowledge and performance

To measure students' prior knowledge and performance, a 14-item multiple-choice test was used to assess students' understanding of scientific concepts on percentile motion (including angle, initial speed, mass, and air resistance). This test has been revised numerous times according to science teachers' suggestions and pilot test results from similar samples. Because no direct teaching was involved in this study, a gain in the performance scores would indicate that the student had acquired a good understanding of the scientific concepts after being exposed to the CIS learning environment.

5.3.2. Goal orientation

The Approaches to Learning (ATL) scale was used to assess three types of student achievement goals: learning, performance-approach, and performance-avoidance. The ATL was originally developed in English and has since been used successfully in studies of American high school students (Greene et al., 2004; Hardré & Reeve, 2003). In this study, we used a version that was translated and tested with Taiwanese high school students (Hardré et al., 2006). Some of the original items were modified to fit this particular learning context. Sample items included: learning goals subscale ("I do my work in the CIS because I want to understand the ideas"), performance-approach goals subscale ("I do my work in the CIS so that I can show other people that I am smart"), and performance-avoidance goals subscale ("I don't do my work in the CIS because I want to avoid looking stupid to others"). The 18 items utilized a 5-point scale from: 1 = strongly disagree to 5 = strongly agree. The subscale reliabilities were as follows: learning goals ($\alpha = .81$), performance-approach goals ($\alpha = .77$), and performance-avoidance goals ($\alpha = .71$).

5.3.3. Need for cognition

The 18 items, 5-point Need for Cognition (NFC) (Forsterlee & Ho, 1999) scale assesses individual cognitive preference for deep thinking and ill-structured problems was used. In this study, we used a Chinese version of NFC that had previously been used to study Taiwanese high school students (Hardré et al., 2006). Sample items included: "I would prefer complex to simple problems" and "I only think as hard as I have to." The reliability coefficient was found at $\alpha = .84$.

5.3.4. Metacognitive strategy use questionnaire

After reviewing various tools used to assess motivation and learning strategies (i.e., metacognition), the Motivated Strategies for Learning Questionnaire (MSLQ) (Pintrich, Smith, Garcia, & McKeachie, 1991) was selected for use in this study as a primary assessment tool because it had been used widely in many contexts, particularly in online learning (e.g., Chang, 2007; Matuga, 2009). For this study, a modified version of the MSLQ contained 10 items from the learning strategies subscales utilizing a 5-point scale from: 1 (strongly disagree) to 5 (strongly agree). Sample items included: "I have asked myself at least twice that I understand the question" and "I have asked myself if I have encountered a similar problem before." Reliability coefficients for metacognitive strategies scales were $\alpha = .82$.

5.4. Procedures

Prior to the study, students were asked to complete prior-knowledge tests and self-report questionnaires on goal orientation and need for cognition. In the first week, the researchers introduced students to the CIS. In the following weeks, students were asked to log in to the system and proceed to the courseware and simulation activity at their own pace. Students spent 50 min each week learning from CIS over a period of three weeks. The learning process was self-directed, and the assistance from the teacher and researchers was available when needed. In the fourth week, students were asked to complete a performance test and metacognitive strategy use questionnaire.

5.5. Data analysis

Three sets of analyses were conducted. The first set of analyses examined the bivariate relations among motivational constructs, need for cognition, metacognitive strategy use, prior knowledge, and performance. In the second set of analyses, we tested the hypothesized model shown in Fig. 1 using path analysis, estimated by ordinary least squares regression. In the third set of analyses, we used hierarchical multiple regression procedures to investigate the hypothesis that metacognitive strategy use mediates the effects of motivational factors and prior knowledge on performance in the online learning environment.

6. Results

6.1. Descriptive analyses

Means, standard deviations, and correlations among variables are shown in Table 1. The expected pattern of results was found among motivational variables, goal orientations and need for cognition. Learning goals had significant positive correlations with performance-approach goals, need for cognition, and metacognitive strategy use, but had significant negative correlations with performance-avoidance goals. Performance-approach and performance-avoidance goals had negative correlations with need for cognition. Need for cognition had significant positive correlations with learning goals and metacognitive strategy use, but had negative correlations with performance-approach and performance-avoidance goals. Performance was positively related to learning goals, need for cognition, prior knowledge, and metacognitive strategy use. Performance was also negatively related to performance-approach and performance-avoidance goals.

Table 1
Descriptive statistics and zero-order correlations.

| Variables | M | SD | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|--------------------------|-------|-------|--------|-------|-------|-------|-------|------|---|
| LG ^a | 3.48 | .54 | – | | | | | | |
| PG ^a | 3.17 | .79 | .33** | – | | | | | |
| PAVG ^a | 3.01 | .65 | -.43** | -.11* | – | | | | |
| NFC ^a | 3.13 | .40 | .63** | -.09 | -.42* | – | | | |
| PK ^b | 72.14 | 24.71 | .19 | -.03 | .14 | .17 | – | | |
| MetaCS ^a | 2.84 | .30 | .49** | .18* | .45 | .46** | .08 | – | |
| Performance ^b | 88.44 | 24.45 | .12* | -.03 | -.29* | .03* | .51** | .07* | – |

Note. 1. LG: Learning goal; 2. PG: Performance-approach goal; 3. PAVG: Performance-avoidance goal; 4. NFC: need for cognition; 5. PK: prior knowledge; 6. MetaCS: Metacognitive strategy use; ** $p < .01$; * $p < .05$.

^a Range from 1 to 5.

^b Max. score: 140.

6.2. Path analyses

Fig. 1 portrays the hypothesized model used to assess the relations among achievement goals, need for cognition, metacognitive strategy use, prior knowledge, and performance. Preliminary analyses were conducted to ensure that all assumptions of path analyses were met. Separate path analyses were then conducted for each of the achievement goals to examine the direct and indirect relations among the variables. The path models were constructed in two steps. First, metacognitive strategy use was separately regressed on the prior knowledge and motivational variables (learning goals, performance-avoidance goals, performance-approach goals, need for cognition). Second, student performance was separately regressed on the motivational variables, prior knowledge, and metacognitive strategy use. Significant paths of the fully estimated path models are shown in Fig. 2. Standardized beta coefficients are reported, and the path coefficients illustrate the strength of each explanatory variable, controlling for all other explanatory variables in the model.

Results are organized around the two sets of relations proposed in Fig. 1: (a) influences on metacognitive strategy use, and (b) influences on performance.

Influences on the metacognitive strategy use. The metacognitive strategy use was regressed on prior knowledge, learning goals, performance-approach goals, performance-avoidance goals, and need for cognition. Learning goals and need for cognition were positive influences ($\beta = .12, p < .01$, and $\beta = .01, p < .05$), indicating that students who were concerned with understanding the content to advance their knowledge and who were inclined for deep and thoughtful engagement were more likely to report higher uses of metacognitive strategies. Prior knowledge, performance-approach goals, and performance-avoidance goals negatively influenced metacognitive strategy use in online learning ($\beta = -.04, p < .01$, $\beta = -.17, p < .01$, and $\beta = -.34, p < .01$, respectively, see Fig. 2). Adolescents' levels of prior knowledge, high in reported performance-approach goals and performance-avoidance goals, were less likely to use metacognitive strategies while learning online.

Influences on online performance. The full model explained 38% of the total variance in online performance (see Fig. 2). The metacognitive strategy use was a positive influence ($\beta = .03, p < .05$) in online performance. Thus, when students used more metacognitive strategies to guide their learning processes, they performed better.

6.3. Metacognitive strategy use as mediator between cognition, motivation, and performance

The next set of analyses was conducted to determine whether metacognitive strategy use mediated the relationship between students' cognitive/motivational factors and performance. The path analysis results reported above establish that a significant relation exists between

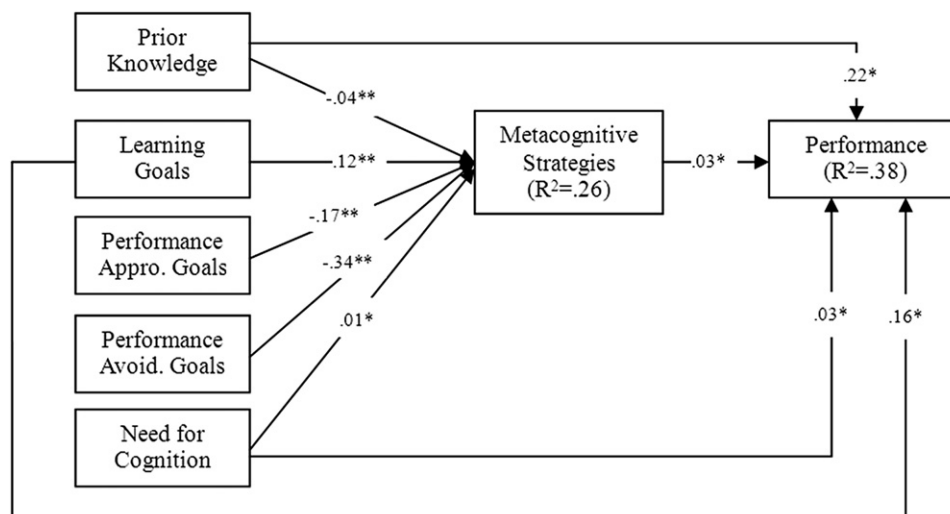


Fig. 2. Results of path analysis explaining online performance. Only significant paths of the fully estimated model are shown. Standardized regression coefficients are presented. * $p < .05$. ** $p < .01$.

the independent variables (cognitive and motivational factors) and the mediating variable (metacognitive strategy use), and a significant relation exists between the mediating variable and the dependent variable (performance). Specifically, learning goals and need for cognition explained metacognitive strategy use, which in turn explained performance. To establish the relationship between the independent variable and the dependent variable, we used hierarchical multiple regression analyses with the cognitive and motivational variables entered in the first step and metacognitive strategy use entered in the second step. These analyses allowed us to determine the relationships between learner variables and performance independent of metacognitive strategy use. Further, we were able to examine the degree to which the regression coefficients for the learner variables were attenuated after metacognitive strategy use was entered into the regression.

Table 2 presents the results of hierarchical regression analyses. We will now discuss the results relevant in determining whether metacognitive strategy use mediates the relation between cognitive/motivational variables and performance. In the first step of the regression analyses when all learner variables were regressed on performance, all variables except performance-approach goals were significant influences. When the metacognitive strategy use was included in the regression analyses, there was substantial attenuation in the regression coefficients. The prior knowledge's beta coefficient dropped from .04 to .03 and was no longer significant. This suggests that the effect of prior knowledge on performance was mediated by metacognitive strategy use. The learning goals coefficient dropped from .25 to .16 but remained significant. The need for cognition coefficient dropped from .07 to .03 but remained significant. This suggests that the effects of learning goals and need for cognition on performance was partially mediated by metacognitive strategy use. Performance-avoidance goals were not related to performance and thus, there was no requirement for mediation testing.

7. Discussion and implications

This study set out to test relationships between cognitive/motivational factors and metacognitive strategy use while also investigating how they collectively and differentially affect high school students' performance in an online learning environment. Relationships between motivational goals and learning environments have been widely demonstrated, but little research has been done on the relationships between online learning and goals, and still even less in East Asian cultural contexts where the educational system is rooted in socio-cultural values. Given the potential influences of culture and context on students' educational experiences, this research is essential. Thus, the present study makes three major contributions to the literature. First, it combines cognition and motivation in a single study, both of which are recognized as influential factors, but which have rarely been studied in tandem. Second, it takes into consideration the need for cognition, which can potentially shed additional light on the investigation of these other influential motivational factors. Third, it tests how these relationships influence metacognitive strategy use and performance.

The results of our statistical finding indicate that learning goals and need for cognition are important motivational factors in explaining online performance. Learning goals represent the desire to know and understand (not just to be "right" or to "get it done"). Need for cognition signifies the desire to think and know, not simply but deeply; a student with a high need for cognition uses learning strategies differently from a student who prefers simple questions with easy or "right" answers. Both learning goals and need for cognition are positively correlated and account for a large portion of the variance in student's metacognitive strategy use and online performance. The combination of learning goals and need for cognition can help to explain metacognitive strategy use in order to regulate their own learning processes in online learning, which, in turn, influences learning outcomes. This finding provides important evidence that extends the current research on whether learning goals influence learning strategy use in online contexts (Alevin et al., 2003; Jiang et al., 2009). Moreover, this study confirms that learning goals and need for cognition are motivational indicators that affect the depth of processing and performance in goal-directed online contexts (Vansteenkiste et al., 2004).

Prior knowledge is an important determinant of successful learning outcomes in both the traditional and online learning contexts (e.g., Akyol, Sungur, & Tekkaya, 2010; Dochy, 1992; Liu, Andre, & Greenbowe, 2008). In the present study, students' prior knowledge was found to be related to their online performance. However, levels of prior knowledge predict neither metacognitive strategy use nor learning goals and need for cognition. McInerney (2008) suggests that the nature of strategy use may not be the same across cultures. For example, in cultures embedded with traditional values like collectivism or Confucianism, emphasis is placed on conformity to group norms for realizing valued goals and outcomes; this may lead more toward utilization of rehearsal strategies and less toward organization or deep processing strategies. Kurman (2001) also suggests that students can perform well in learning environments that correspond to their culture's emphasis on learning. Therefore, if students from collective cultures are placed in less structured learning environments, such as student-centered, goal-directed online contexts, they may not perform well.

When the relationship between metacognitive strategy use and online performance was taken into consideration, it appeared that metacognitive strategy use had positive relationships with students' online performance. This finding confirms the previous study's results that students depending on deeper processing strategies (i.e., elaboration, critical thinking and metacognitive self-regulation) for

Table 2
Summary of hierarchical regressions.

| Predictor | β^a | β^b | R^2 | ΔR^2 |
|------------------------------------|-----------|-----------|-------|--------------|
| <i>Performance</i> | | | | |
| Step 1: Learner variables | | | .22* | |
| Prior knowledge | .04* | .03 | | |
| Learning goals | .25** | .16* | | |
| Performance-approach goals | -.05 | .03 | | |
| Performance-avoidance goals | -.20** | -.13* | | |
| Need for cognition | .07** | .03* | | |
| Step 2: Metacognitive strategy use | | | .38* | .04* |

* $p < .05$. ** $p < .01$.

^a Standardized regression coefficients without metacognitive strategy use entered into the regression.

^b Standardized regression coefficients with metacognitive strategy use entered into the regression.

information processing were more likely to obtain high scores (Linnenbrink & Pintrich, 2003; Pintrich & De Groot, 1990). Additionally, this study's findings provide support for the idea that metacognitive strategy use explains, in part, why and how learning goals and need for cognition affect online performance. Students that reported learning goals and high need for cognition were likely to adopt metacognitive strategies, but those who reported more performance-approach and performance-avoidance goals were less likely to adopt such strategies in online learning. These findings add to the growing body of evidence that supports the vulnerability hypothesis of online learning contexts by showing that perceptions of cognitive, motivational, and metacognitive strategy use are positively related to online performance.

The present study's findings can have practical implications for teachers, online learning designers and developers. Teachers, for example, may take into consideration differences in students' characteristics, such as prior knowledge and goal orientation, and how these differences affect learning. They may signify the importance of knowledge and skill mastery rather than outcome or performance orientation. Moreover, teachers should teach students about learning strategies and also about when and how to use them. Online learning environments may include learning tasks that encourage students to engage in the learning process actively and to use deeper processing strategies such as metacognitive strategies. Online learning environments should also provide timely support that focuses on how much students can learn while also showing them that making mistakes is part of the learning process. E-learning systems should also avoid the use of competition and should instead emphasize how the learned material is applicable to the real world so that students learn to develop skills and acquire knowledge.

8. Future research

This study was not structured as an experimental study; instead, we examined the effects of student cognition and motivation, while mediating metacognitive strategy use, in order to understand how these variables directly and indirectly, positively and negatively, influenced online performance. Based on the results, this study has provided valuable insights into our understanding of students' cognitive and motivational factors in a technology-rich, supportive online learning environment. Our exploratory study suggests that further research is needed to examine how individual differences in prior knowledge, goal orientation, and need for cognition affect learning strategy use and responses and reactions to learning tasks. Furthermore, future research should conduct holistic approach to investigate whether learner's characteristics to online learning and characteristics of online learning environment itself mediate the relationship between learners' cognitive/motivational factors and performance. Such holistic approach can help us better understand how the differences in learner's characteristics and features of online learning environment affect learning. Replications of the current study will also be necessary to see if the results hold true with students of other age groups.

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