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Students' math performance in higher education: Examining the role of self-regulated learning and self-efficacy

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ABSTRACT

Research on the role of learning strategies and self-efficacy for mathematics performance in higher education is sparse, especially if cognitive and metacognitive strategies are considered. In response, the current study investigated the associations between these variables with a sample of 206 university students in the context of a two-semester math course. Self-efficacy measured after one semester (t2) was positively related to both cognitive and metacognitive strategy use at the beginning (t1) and the end of the math course (t3). The use of either strategy was stable from t1 to t3. Once the variance overlap between the learning strategies was controlled for, metacognitive strategy use at t1 was positively and at t3 negatively associated with performance in the math course exam at t4. Greater levels of self-efficacy at t2 also predicted a better exam performance. Future longitudinal research is warranted to demonstrate the causal role of self-efficacy as a mediator between learning strategy use on math performance. In terms of implications, interventions may help to foster the students' awareness for an integrated use of cognitive and metacognitive strategies.

1. Introduction

Mathematics is considered a key subject in higher education. Mathematical skills are required for most college degrees and thus serve as a gatekeeper to careers in many domains such as science, engineering, or technology (National Mathematics Advisory Panel, 2008; Reyes, 2010). Despite their benefits, many students express dislike about mathematics courses as they carry a risk of failure and negative performance evaluations and may trigger the experience of stress and anxiety (Goetz, Bieg, Lüdtke, Pekrun, & Hall, 2013; Ma & Kishor, 1997). Mastering an introductory math course at college may thus create a barrier for students to complete their studies in higher education and may limit their career opportunities (National Mathematics Advisory Panel, 2008; Reyes, 2010).

In response, research has made an effort to identify and strengthen those factors in students which influence their performance in mathematics. For the context of schooling, research has identified competence beliefs like self-efficacy (Bonne, 2016; Burrus & Moore, 2016; Ma & Kishor, 1997) and the use of learning strategies (Kiliç, Çene, & Demir, 2012; OECD, 2010) as major determinants of math performance. For the context of higher education, however, empirical evidence is limited, especially when the combined effects of self-regulated learning and self-efficacy on mathematics performance are considered. Instead, research has yielded multiple evidence that learning strategies and/or self-efficacy constitute important predictors of general academic performance at university (for an overview see e.g., Richardson, Abraham, & Bond, 2012; Robbins et al., 2004; Zimmerman & Schunk, 2011). Moreover, research in higher education lacks an investigation of the reciprocal effects between cognitive and metacognitive learning strategies over time (Geitz, Joosten-ten Brinke, & Kirschner, 2016). Based on the process model of self-regulated learning by Schmitz and Wiese (2006), the current study thus investigated predictors of math performance in university students over time, thereby examining the significance of the indirect pathway through self-efficacy between repeated assessments of cognitive and metacognitive strategies.

1.1. Self-regulated learning

Self-regulated learning is characterized as "an active, constructive process whereby learners set goals for their learning and then attempt to monitor, regulate, and control their cognition, motivation, and behavior, guided and constrained by their goals and the contextual features in the environment" (Pintrich, 2000, p. 453). In order to facilitate, manage and control the learning process, students may engage in

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different strategies (Boerner, Seeber, Keller, & Beinborn, 2005; Marsh, Hau, Artelt, Baumert, & Peschar, 2006): Cognitive (elaboration) learning strategies like *rehearsal* and *establishing associations* refer to mental activities with a focus on information processing. They help students to link new information with existing knowledge, extend and organize existing memory structures, and facilitate the storage in long-term memory. Metacognitive (control) activities, on the other hand, help students to control the context-specific use of cognitive strategies. They refer to regulatory behaviors which are necessary to adapt and monitor the learning process. Metacognitive strategies are essential for students to control their attention and interest. For math performance, the metacognitive skills of *prediction, goal-setting and planning, monitoring* and *evaluation* are relevant (Lucangeli & Cornoldi, 1997). Finally, students may engage in resource management strategies to organize the environment as an external resource, or keep up concentration as an internal resource. Since cognitive and metacognitive strategies constitute more important predictors of performance than resource management (Boerner et al., 2005; Richardson et al., 2012; Robbins et al., 2004; Zimmerman & Schunk, 2011), we decided to focus on the initial two in the current study.

Many researchers understand self-regulated learning as a dynamic process which involves an adaptive use of learning strategies to situational and motivational circumstances which is in part guided by competence beliefs like academic self-efficacy (e.g., Boekaerts & Cascallar, 2006; Pintrich, 2000; Schmitz & Wiese, 2006; Zimmerman, 2000). For instance, Boekaerts' (1999; Boekaerts & Cascallar, 2006) model of self-regulated learning conceptualizes the interdependency of self-regulatory processes at three different layers. The inner layer characterizes different modes of information processing by means of cognitive learning strategies. Selecting the appropriate strategy is crucial for the quality of learning, as students have to adapt their learning to the contents and the complexity of the study materials. The intermediate layer portrays the regulation of the learning process itself which requires the students to build-up and use metacognitive knowledge and monitoring skills. Successful students oversee the effectiveness of a particular strategy, and modify its use for a different context while low achieving students depend on external guidance. The outer layer depicts motivational processes which are a prerequisite for the student to set up adequate achievement goals, initiate and reflect upon the learning behavior, and deal with set-backs and obstacles.

Boekaerts model distinguishes between internal and external motivators of self-regulated learning. In line with the tenets of social-cognitive theory, self-efficacy constitutes an important internal determinant (Putwain, Sander, & Larkin, 2013), whereas external determinants may be environmental conditions (e.g. noise, temperature), or support from classmates, parents, or teachers (Boekaerts & Cascallar, 2006; Zimmerman & Schunk, 2011). In educational settings, academic self-efficacy designates the conviction of being capable to cope with academic demands, successfully complete performance-related tasks, and reach academic goals (Jerusalem & Satow, 1999; Putwain et al., 2013).

Building on the work of Zimmerman and colleagues (Schunk & Zimmerman, 2007; Zimmerman & Cleary, 2006), the dynamic relationships between self-efficacy, learning strategies, and academic performance are depicted in the process model of self-regulated learning by Schmitz and Wiese (2006). The model differentiates three phases: Students set goals and plan their learning in the pre-action phase, engage in cognitive, metacognitive and resource management strategies to reach those goals in the action phase, and reflect on the quality of the learning and its outcomes in the post-action phase which, in turn, may alter self-efficacy beliefs and thus influence goal-setting and learning preparation in the subsequent pre-action phase. In essence, students' learning can be modelled as a recursive learning cycle, during which self-efficacy may serve as an intervening variable between the use of learning strategies over time. If Usher and Pajares' (2008) research is integrated into the model, the relationship between learning strategy use and self-efficacy may be depicted as follows: If students reflect upon their strategy use during a learning period after completing a task or an examination they can infer its effectiveness. If the learning efforts lead to the desired outcomes, the students thus collect mastery experiences which enhance their sense of self-efficacy. In addition, self-efficacy builds up if students (1) identify successful learning efforts in comparison to the approaches of fellow students, (2) receive feedback on their strategy use (e.g. from teachers), and/or (3) experience a medium level of emotional arousal during learning activities as an indicator of competence. Increasing self-efficacy, in turn, should foster the application of successful learning strategies in subsequent learning periods, and the modified use of less successful strategies. With regard to metacognitive strategies, Zimmerman and Cleary (2006) suggest that the metacognitive strategies *goal setting* and *planning*, in particular, constitute important determinants of self-efficacy beliefs.

1.2. Associations between metacognitive and cognitive learning strategies

A number of studies have examined the parallelized use of different learning strategies as performance predictors (e.g., Geitz et al., 2016; Nett, Goetz, Hall, & Frenzel, 2012). However, only few studies have investigated the stability of a particular strategy, or the reciprocal relationships between metacognitive and cognitive learning strategies over time, especially in the context of higher education. The model of self-regulated learning (Schmitz & Wiese, 2006) posits that different learning strategies are likely to co-occur as indicated by positive cross-sectional associations. For instance, using cognitive learning strategies successfully (e.g., establishing associations) requires the students to concurrently plan, monitor and evaluate their effectiveness. Moreover, the model assumes that students use learning strategies in a cyclical manner, which may result in high stability for a particular strategy, and in positive associations between strategies over time. For instance, using metacognitive strategies (e.g., goal-setting and planning) in the pre-action phase may prompt a greater engagement in cognitive strategies during the action phase, which is assumed to recursively influence the use of the initial strategy (e.g., modified planning) in subsequent learning periods through feedback loops.

Based on samples of university students, a few studies yielded evidence for moderate to high stability in strategy use, and positive associations between cognitive and metacognitive learning strategies, both cross-sectionally and longitudinally across intervals of one year. Using a longitudinal design with three annual waves, Coertjens, Donche, De Maeyer, Vanthournout, and Van Petegem (2013) applied latent growth analysis to examine the differential development in cognitive (e.g., establishing associations) and metacognitive learning strategies (e.g., planning and monitoring). Results confirmed strong longitudinal measurement invariance, moderate to high stability, and positive growth trajectories for all cognitive subscales and most of the metacognitive subscales. Based on a longitudinal within-subjects design with two annual assessments, Vermetten, Vermunt, and Lodewijks (1999) found moderate stability in metacognitive and cognitive learning strategies, while the underlying factor structure became clearer over time. Ning and Downing (2010) assessed learning strategy use in a sample of Chinese students. They found partial support for strong longitudinal measurement invariance for cognitive and metacognitive strategies with moderate stability coefficients over a period of 12 months. In essence, results suggest that the students' strategy use shows moderate to high stability, while the students, on average, shift towards deep-level approaches with differentiated albeit associated use of cognitive and metacognitive strategies.

1.3. The interplay of academic self-efficacy, learning strategies, and performance

Research has yielded multiple evidence that self-efficacy and the use of learning strategies predict academic performance in higher