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Higher-order structure of noncognitive constructs and prediction of PISA 2003 mathematics achievement

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ABSTRACT

The present study investigates higher-order factor structure among fifteen primary variables selected from four broad noncognitive domains of academic self-beliefs, motivation, learning strategy, and attitudes toward school. The PISA 2003 international dataset was analyzed. Several EFA, CFA, and SEM models were tested, hypothesizing the structure among the primary first-order variables and their relationships to the mathematics scores. The analyses indicated no single, general factor at the second-order level, encompassing all fifteen first-order variables. Instead, the fifteen primary variables were best represented by a three-level factor structure with the four salient domain factors at the second-order level and one general noncognitive factor at the third-order. The most plausible SEM model had each of the three self-belief primary variables individually linked to the mathematics achievement scores, independent of the third-order factor. Self-efficacy was the strongest predictor of mathematics achievement and its predictive power was comparable to that of the common part of all 15 primary variables captured by the general noncognitive factor.

Within the subfields of psychology such as intelligence and personality, there has been a long history of examining the structure of their "major" constructs. In contrast, ever since the concept of motivation gained its prominence (e.g., Atkinson, 1957, 1964; Cofer & Appley, 1967; Goldthorpe, Lockwood, Bechhofer, & Platt, 1968; Vroom, 1964), there has been relatively little interest in educational psychology to identify the overall structure of its well-established psychological constructs. By "major" constructs, we mean those constructs that have been well-defined theoretically and empirically, that have "survived" years of rigorous research, and have proven strong links to meaningful outcome measures such as academic achievement. Many psycho-educational constructs with such properties have been identified in a recent review paper (Lee & Shute, 2010). Researchers have also continued to highlight considerable (empirical and theoretical) commonalities among them (cf, Martin, 2007, 2009). The goal of the present study is (1) to investigate the overall structure underlying a group of major student-related psychological constructs that have relevance to education, and (2) to assess the effectiveness of the structure in predicting students' academic achievement. We examine whether the fifteen psychological constructs selected for this study can be reduced to a smaller number of domains and whether there is one general, higher-order construct that can reasonably represent them.

1. PISA 2003 data source

The present study adopts the 2003 data of a large-scale international survey, known as the Programme for International Student Assessment (PISA) (see OECD, 2004a).[1] Fifteen psychological constructs measured in the PISA 2003 assessment were employed in the present study. Those constructs are: interest in math; instrumental motivation in math; math self-efficacy; math self-concept; math anxiety; control; elaboration; memorization; competitive learning; cooperative learning; attitudes toward school; student–teacher relationships; sense of belonging to school; teacher support in math lessons; and disciplinary climate in math lessons (see Appendix 1 for definitions of each construct and the questionnaire items). We label all fifteen constructs collectively as "noncognitive" constructs. We use the term "noncognitive" in the way that was conceptualized in Bowles and Gintis (1976, 2000, 2002), Farkas (2003) and Messick (1979). In their definition, noncognitive constructs are referred to as all psychological and behavioral dispositions, tendencies, and habits that are not measured by typical cognitive tests such as tests of school performance,

[1] Test/survey developers in a well-established large-scale assessment (e.g., PISA) follow an extensive procedure to select the variables for their survey instruments. The variables are selected based on their conceptual clarity, well-defined factorial structure, and strong psychometric properties, and should have clear relevance to academic achievement and be known to be amenable to change through meaningful interventions. Leading experts in diverse fields (e.g., education, psychology, sociology, economics, cross-cultural psychology, and measurement/evaluation) participate in the variable selection process. As a result the selected variables tend to reflect different theoretical backgrounds.

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ability, and aptitudes. We recognize that noncognitive constructs have a component of cognition. Similarly, cognitive skills require some level of noncognitive capacity. Thus, cognitive and noncognitive variables are typically correlated with each other. It is a usually a matter of degree: there is hardly any construct that is "purely" cognitive or "purely" noncognitive (Farkas, 2003).

The fifteen constructs examined in this study have been traditionally explored within four broad domains or theoretical streams, namely, motivation, self-beliefs, learning strategies/preferences, and attitudes towards school, which are the building blocks of the present study. Motivation constructs have evolved from expectancy-value theory (Atkinson, 1957; Eccles, Midgely, & Adler, 1984; Elliot & Dweck, 2005; Vroom, 1964; Wigfield & Eccles, 2000), intrinsic and extrinsic motivation (Deci & Ryan, 1992; Lepper, Corpus, & Iyengar, 2005; Schwinger, Steinmayr, & Spinath, 2009); theory of performance-contingent rewards (e.g., Bandura, 1986, 1997; Cameron, Pierce, Banko, & Gear, 2005; Schunk, 1991), attribution (Weiner, 1986), goal orientation (Ames, 1992; Elliot & Harackiewicz, 1996), and interest development (Krapp, 2005; Renninger, Hidi, & Krapp, 1992). Two extensively studied motivational constructs, intrinsic (interest in math) and extrinsic motivations (instrumental motivation in math), are employed in the current study. The two self-beliefs constructs that have received much attention in relation to student achievement are arguably: self-concept (Harter, 1985a, 1985b; Marsh, 1986, 2007) and self-efficacy (Bandura, 1986, 1997; Pajares, 1996; Schunk, 1991). In addition, emotional regulation and affective aspects of self are often indexed by students' tendency to feel anxious when they face specific academic tasks (i.e., anxiety) (Pekrun, Goetz, Titz, & Perry, 2002; Schutz & Davis, 2000; Schutz & DeCuir, 2002). These three self-related constructs are included in the present study. Advances in the conceptualization of learning strategies were made within the theoretical framework of self-regulated learning (Mayer, 1998; Pintrich, 2000; Schunk & Zimmerman, 2003; Zimmerman, 1990, 2001), which emphasizes control/metacognition, elaboration, and review/rehearsal/memorization (e.g., Borkowski, Johnston, & Reid, 1986; Cardelle-Elawar, 1992). Two types of learning style, cooperative and competitive learning, have gained much attention of researchers and practitioners (see Johnson & Johnson, 1989; Slavin, 1980, 1996). These five constructs can be grouped as approaches to learning. Social-cognitive theory (Bandura, 1986, 1997; Goodenow, 1992, 1993) highlights the critical roles that teachers play in shaping students' attitudes toward school (Elliot & Dweck, 2005; Radel, Sarrazin, Legrain, & Wild, 2010), student–teacher relationships (Den Brok, Brekelmans, & Wubbels, 2004; Wentzel, 1994) and students' sense of belonging at school (Finn, 1989; Goodenow, 1992, 1993; Voelkl, 1997). These constructs are related to students' general attitudes toward school, classroom, and teachers. Five such constructs are employed in the present study. The present study aims to establish whether the individual fifteen constructs, which have been extensively studied within these theoretical approaches, can be meaningfully related to each other and understood within a broader structural framework.

2. Conceptualizing a higher-order structure

Many empirical studies have hinted at the possibility of a higher-order structure among the major four domains of constructs that are the focus of this paper — i.e., motivation, self-beliefs, learning strategies/preferences, and attitudes towards school. First, there may be higher-order constructs within the domain-level. Marsh and his colleagues (Marsh, Hau, Artelt, Baumert, & Peschar, 2006) showed that primary constructs of academic self-beliefs had substantial correlations with each other (e.g., correlations between .66 and .91 among academic self-concept, self-efficacy, and control expectations). Other studies (e.g., Lee, 2009; Pajares & Miller, 1994) reported similar (or even higher) correlations among the variables belonging to the same domain, suggesting the presence of a higher-order factor among the within-domain variables.

Second, it is often reported that there are substantial correlations among the constructs across the four domains. For example, the motivation constructs in the PISA 2000 data were substantially related to all three learning strategies variables — i.e., control, elaboration, and memorization (rs = .52 to .93) (Marsh et al., 2006). Similarly, these learning strategy variables showed substantial correlations with the academic self-beliefs variables (rs = .67 to .76). Martin (2007) also found that the constructs of self-beliefs, intrinsic motivation, and attitudes toward school were all substantially correlated with each other (rs = .73 to .79). He also noted that students' attitude toward school was substantially correlated (r = .51 and .58) with their use of learning strategy in planning and task management (Martin, 2009). The substantial size of cross-domain correlations is suggestive of a potential higher-order structure among the domain-level constructs. In other words, the commonality (i.e., shared variances) among the cross-domain constructs can be captured by a broader construct.

Third, from the theoretical point of view, the four constructs at the domain-level tend to share antecedents and are linked to the same or similar types of outcome variables (see the following three sections describing the conceptual links). Furthermore, the item content across the four domains (see Appendix 1) seems to have substantial overlap and may be open to questions about their face validity. For instance, "I am just not good at mathematics" and "I worry that I will get poor marks in mathematics" belong to different domain level constructs (self-concept versus anxiety).

In sum, previous studies (Lee, 2009; Marsh et al., 2006; Martin, 2007, 2009; OECD, 2004a) have reported substantial correlations among the variables within and across the theoretical domains of interest in this paper. The domain-level variables have been linked to similar types of antecedents and outcomes. This observation suggests that there may be an overarching structure that can capture the relationships within and across the domain-level variables.

In the following sections we elaborate on some of the theoretical accounts about how the four domain-level constructs relate to each other. We then present empirical evidence about their particular relationship to academic achievement.

3. Conceptual links between motivation and self-beliefs

Motivation (e.g., Atkinson, 1957; Eccles et al., 1984; Elliot & Dweck, 2005; Schunk, 1991; Skinner, Furrer, Marchand, & Kindermann, 2008; Vansteenkiste, Lens, & Deci, 2006; Vroom, 1964; Wigfield & Eccles, 2000) directs and drives one's mental and emotional energy and efforts to work toward attaining the goal. It is characterized by desire, persistence, and expectations for success, which governs one's behavior toward achievement by planning, monitoring and regulating. In the expectancy-value theory of motivation (Atkinson, 1964; Wigfield & Eccles, 2000), self-belief is one of the critical components of motivation. The theory asserts that motivation to do well in a particular task is linked to individuals' perception of the likelihood of obtaining positive outcomes (i.e., perceived outcome expectancy), their perceived competency in mastering the task by their own abilities (self-efficacy), and their personal, intrinsic values to the particular task (e.g., Becker, McElvany, & Kortenbruck, 2010; Deci & Ryan, 1992; Vansteenkiste et al., 2006). Some researchers (e.g., Bandura, 1997; Pajares, 1996) see academic self-beliefs (self-efficacy in particular) as an active state of motivation (cf, Martin, 2007). Intrinsic motivation and self-beliefs often coexist in one's desire to do well on a particular task (Schunk, 1991). Thus, if these two constructs of motivation and self-beliefs are examined with a large set of measures, it is possible that a high-level of commonality between them will make it hard to tease them apart empirically.

Research has also indicated that motivation and academic self-beliefs share the same antecedents and are linked to a common set