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Predicting Complex Problem Solving and school grades with working memory and ability self-concept

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ABSTRACT

In addition to established criteria such as school grades, recent educational research has emphasized the role of students' Complex Problem Solving (CPS) ability as a criterion for success in the school context and future success. The present study examined cognitive and motivational predictors of both CPS and school grades. We investigated a sample of 393 German students (235 female) in Grades 10 to 13 from the highest academic track. CPS and grade point average were applied as achievement criteria. Working memory capacity (WMC) and domain-specific ability self-concept served as predictors. In a structural equation model, CPS was equally well-explained by WMC and ability self-concept, whereas school grades were best predicted by ability self-concept. Results illustrate that the prediction of CPS with cognitive and motivational predictors differs from that of school grades as another indicator of academic achievement. We discuss the role of different achievement indicators in predicting school achievement.

1. Introduction

In the last decade, students' Complex Problem Solving (CPS) ability has gained importance as an indicator of academic achievement in educational research. The relevance of CPS becomes particularly evident when considering the framework of the Programme for International Student Assessment (PISA by the Organisation for Economic Co-operation and Development, OECD) in which CPS was emphasized as a key competence of future learning and success (OECD, 2014; Wirth & Klieme, 2003). Concerning the fundamental importance of CPS, it is surprising that, to this day, little is known about the different predictors of CPS. In particular, the role of motivational predictors compared with cognitive predictors is often neglected in predicting CPS. Thus, the first aim of the present study was to investigate the relative importance of cognitive and motivational constructs in the prediction of CPS. Furthermore, the understanding of CPS should be improved by comparing its prediction with a more established achievement indicator: school grades. Thus, the second aim of the present study was to fill this research gap by investigating whether the relative importance of cognitive and motivational predictors differs between CPS and school grades.

1.1. Complex Problem Solving

Besides assessing domain-specific achievement such as reading, mathematics, and science, international large-scale assessments focus on cross-curricular competences such as CPS (e.g., PISA, see OECD, 2014; Wirth & Klieme, 2003). Students are faced with various new problem situations at school every day. To deal with these situations, they must be able to explore problem situations strategically, to acquire necessary knowledge about the problem, and to apply this knowledge to solve the problem (Funke, 2001). These aspects of CPS are reflected in Buchner's definition (as cited in Frensch & Funke, 1995):

> Complex Problem Solving is the successful interaction with task environments that are dynamic (i.e., change as a function of the user's intervention and/or as a function of time) and in which some, if not all, of the environment's regularities can only be revealed by successful exploration and integration of the information gained in that process. (p. 14)

Students' CPS abilities represent a fundamental competence in the educational context because these abilities are not only an outcome of teaching processes but also a prerequisite for future learning (Leutner, Fleischer, Wirth, Greiff, & Funke, 2012; see also OECD, 2014). Beyond the mere reproduction of knowledge (e.g., knowing the Archimedes' principle), students learn to apply their curricular knowledge to novel, real-life problems (e.g., building a boat that floats). Students with higher CPS abilities will be more able to use prior knowledge when learning

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new content and thus, their learning might be faster and deeper. Studies have investigated CPS from two perspectives. CPS has been considered an indicator of academic achievement on the one hand (e.g., OECD, 2014) and as a central predecessor of achievement on the other (e.g., Wüstenberg, Greiff, & Funke, 2012). Because a school's central objective is to develop students' CPS performance, we aimed to explain interindividual differences in CPS with cognitive and motivational predictors. Therefore, CPS was investigated as an achievement indicator in the present study.

1.2. Predictors of Complex Problem Solving

Theories explaining CPS focus in particular on its underlying cognitive processes (for a review, see Greiff & Fischer, 2013a). CPS is defined as a composite of different simple and complex cognitive processes (Funke, 2010). Thus, previous studies have mainly investigated the relation between CPS and cognitive constructs (for an overview, see Kretzschmar, Neubert, Wüstenberg, & Greiff, 2016; see also Stadler, Becker, Gödker, Leutner, & Greiff, 2015). Because a substantial portion of variance in CPS has remained unexplained by cognitive predictors (e.g., Bühner, Kröner, & Ziegler, 2008), it is worthwhile to look for additional constructs that might explain differences in CPS.

The PSI theory[1] (Dörner, 1999; see also Dörner & Güss, 2013) emphasizes that, besides cognitive processes, motivational processes should be considered when explaining complex human behavior. According to the PSI theory, a person's intention, which guides a person's behavior, to solve new or unexpected problems depends on the expectancy-value principle. In line with expectancy-value theories, expectations—frequently investigated under the label ability self-concept (Eccles & Wigfield, 2002)—are a better predictor of task performance than values (e.g. Steinmayr & Spinath, 2009; Wigfield & Eccles, 2000). Ability self-concept and performance seem to be mutually reinforcing (e.g., Marsh, Trautwein, Lüdtke, Köller, & Baumert, 2005), whereby the influence of ability self-concept on performance might be explained by its impact on achievement-related behavior (e.g. Abramson, Seligman, & Teasdale, 1978; Bandura & Jourden, 1991). Thus, in line with the PSI theory, ability self-concept should influence a person's behavior when he/she engages in CPS.

Further, the PSI theory highlights the role of cognitive processes, especially of working memory, for CPS (Dörner, 1999). Because human beings have no routine behavior patterns for solving new problems, they have to explore the problem situation and simultaneously store, process, and coordinate new information in working memory (Dörner, 1999; for functions of working memory, see also Oberauer, Süß, Schulze, Wilhelm, & Wittmann, 2000). As working memory capacity (WMC) is limited, CPS performance should depend on WMC (Oberauer et al., 2000). According to this theoretical foundation, WMC and ability self-concept can be considered important predictors of CPS.

Although several studies have illustrated that WMC represents an important cognitive predictor of CPS (e.g. Bühner et al., 2008; Wittmann & Süß, 1999), there are no studies investigating whether ability self-concept contributes to the prediction of CPS beyond WMC. Only one study investigated whether ability self-concept could predict CPS beyond intelligence (Ackerman, Kanfer, & Goff, 1995). Besides other motivational constructs (i.e., negative motivational thoughts), ability self-concept explained a substantial amount of variance in CPS beyond intelligence. Further, the authors concluded that higher order cognitive abilities (i.e., intelligence) contributed more to the prediction of CPS than these motivational constructs. This finding is consistent with the theoretical consideration of CPS as a primary cognitive process that is influenced by motivational processes (Wood & Bandura, 1989). Moreover, Ackerman et al. (1995) surmised that cognitive and motivational predictors could jointly explain a substantial amount of variance in CPS. However, the authors did not examine this shared variance even though it most likely exists and must be acknowledged in order to evaluate the importance of these predictors for achievement (see also Spinath, Spinath, Harlaar, & Plomin, 2006; Steinmayr & Meißner, 2013). Thus, the present study investigated the independent and common portions of variance in CPS explained by WMC and ability self-concept to evaluate the relative importance of these cognitive and motivational constructs in predicting CPS.

1.3. Relative importance of different achievement predictors for different achievement indicators

Little is known about the extent to which the nomological networks of CPS and other indicators of academic achievement (e.g., school grades) differ, such as whether these indicators are explained by the same predictors. When previous studies (Helmke, 1992; Steinmayr & Meißner, 2013) simultaneously considered different achievement indicators (i.e., school grades and achievement tests), they showed that the relative importance of cognitive and motivational predictors differed according to the achievement indicator. Cognitive predictors (i.e., intelligence) explained more unique variance on standardized achievement tests than motivational ones (i.e., self-concept). By contrast, self-concept explained at least as much unique variance in school grades as cognitive abilities.

When comparing CPS and school grades as achievement indicators, previous studies demonstrated that intelligence was more highly correlated with CPS than with school grades (Greiff & Fischer, 2013b; Sonnleitner et al., 2012). We are not aware of any study, with or without cognitive constructs, that investigated ability self-concept as a predictor of both CPS and school grades. A comparison of different individual studies showed that correlations between domain-specific ability self-concept and CPS (Ackerman et al., 1995) were as high as those with school grades (Marsh et al., 2005; Möller, Pohlmann, Köller, & Marsh, 2009). However, these results did not allow any conclusions to be drawn about whether the relative importance of cognitive and motivational constructs differed between CPS and school grades as none of these studies investigated both motivational and cognitive predictors simultaneously with CPS and school grades as achievement indicators in the same sample.

The present study was conducted to advance the understanding of CPS by comparing its predictors with those of more established achievement indicators such as school grades. Our study is the first to investigate whether the relative importance of cognitive and motivational predictors differs between CPS and school grades as different achievement indicators in one sample. Therefore, the fundamental importance of this study is that it provides a systematic comparison of these indicators.

1.4. The present study

The present study examined the extent to which CPS and school grades as indicators of school achievement could be predicted by WMC and domain-specific ability self-concept. Some studies have demonstrated the relative importance of motivational constructs (i.e., ability self-concept) in comparison with higher order cognitive abilities (i.e., intelligence) in predicting school achievement (considered criterion: CPS, Ackerman et al., 1995; school grades, e.g., Steinmayr & Meißner, 2013). We examined whether the results of these previous studies could be confirmed when basal cognitive abilities such as

[1] The PSI theory by Dörner (1999) is named after the Greek letter Ψ as Dörner's theory represents a comprehensive theory of human psychological processes. The PSI theory explains human behavior in terms of motivation, perception, memory, schemas, planning, emotions, and so forth (for an overview, see Dörner & Güss, 2013). Due to the complexity of the theory, we have focused on central components of Dörner's theory (Dörner & Güss, 2013). Specifically, we examined a person's expectations (i.e., ability self-concept) and working memory in the present study as these constructs were emphasized in various theories explaining achievement-related behavior (e.g., SOAR by Newell, 1987; expectancy-value model by Eccles et al., 1983).

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