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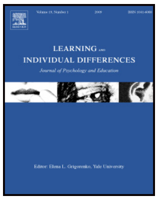

On the relation of complex problem solving, personality, fluid intelligence, and academic achievement

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ABSTRACT

Complex Problem Solving (CPS) is an important cognitive skill that is currently included in a number of educational large-scale assessments. However, only few studies elaborate empirically on the assessment of CPS and its construct validity. The present study aims at reducing this gap by targeting (1) the internal structure of CPS, (2) its relations to personality, and (3) its relations to fluid intelligence and academic achievement in a sample of 490 German students attending grades 8 to 13. Results indicated that (1) CPS was best described by a 2-dimensional model with knowledge acquisition and knowledge application as defining components, (2) relations between CPS and personality were generally weak, and (3) CPS and fluid intelligence exhibited moderate correlations. Further, CPS incrementally predicted academic achievement beyond fluid intelligence. Overall, this study points to the relevance of CPS in predicting academic achievement and empirically advances knowledge of CPS in educational contexts.

1. Introduction

Through history, problem solving has always been a critical part of human existence: From cave dwellers solving the problem of how to survive in times of drought all the way to social workers dealing with the complex situations and problems resulting from drug abuse, problem solving has been a major part of our everyday experience in a variety of forms and fields (Jonassen, 2004). And yet, whereas the tremendous importance of problem solving for human existence is undisputed, questions on how to describe problem solving and how to make humans better problem solvers await further answers. To this end, scientists have tackled the issue of problem solving from different angles. A widely acknowledged definition is found in Lovett (2002). She defines problem solving as cognitive processing aimed at transforming a given state into a goal state when no obvious method of solution is available.

Importantly, problem solving takes place in almost any context and researchers from different fields have recurrently emphasized its significance. As a result, research on problem solving is no consistent field of study and Sternberg (1995) distinguishes two major lines of research. Whereas one line conducts research on domain-specific problem solving in different educational areas such as scientific, mathematical, or technical problem solving, the other is concerned with general mental processes associated with problem solving. Both lines of research show considerable overlap. For example delineating the process of problem solving into components of knowledge acquisition and knowledge application is found in the domain-specific and in the domain general approach toward problem solving (cf. Mayer & Wittrock, 2006; Novick & Bassok, 2005). That is, even though the two lines of research focus their attention on different aspects of problem solving due to their origins in the domain-specific and general cognitive fields, there are ongoing efforts to merge and comprehensively integrate insights gained in either of the two lines (e.g., Hambrick, 2005; Scherer & Q2 Tiemann, 2013). Sternberg (1995) reminds us that particular the second line of research has been somewhat neglected in the past. Consequently, the knowledge on domain general aspects of problem solving is small compared to the knowledge that has been gathered on domain-specific problem solving. To this end, the main focus of the present article lies in the second line of research that investigates general mental processes involved in problem solving.

This article is situated within the line of inquiry that targets domain-general problem solving, a research line that is closely related to the field of Complex Problem Solving (CPS), which covers domain-general and intransparent problem situations within computer simulated environments (Funke, 2001). The study was aimed at providing answers to three questions with regard to CPS: (1) What are—conceptually and empirically—the defining components of CPS (i.e., dimensionality of CPS); (2) How is CPS related to personality (i.e., to the Big Five); and (3) How is CPS related to general cognitive ability and academic achievement (i.e., fluid intelligence and school grades). Answers to these questions are based on a sample of German high school students aged between 14 and 20 years.

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1.1. The concept of Complex Problem Solving

In the research line on general processes of problem solving identified by Sternberg (1995), a broad CPS construct is assumed, strongly focusing on strategic, representational, and processing aspects of problem solving behavior in novel situations (Greiff, Holt, & Funke, 2013). According to Funke (2001), mastering a characteristic complex problem situation involves extracting relevant but at the outset hidden information, establishing a representation of the problem, which is continuously updated, and applying procedural skills to control a dynamically changing environment of interconnected variables. Buchner (1995) emphasizes the interactive nature of CPS in his definition. He understands CPS as

> The successful interaction with task environments that are dynamic (i.e., change as a function of 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).

Raven (2000) and Funke (2010) conclude that CPS requires a number of complex cognitive operations largely independent of rote learning and factual knowledge. To this end, research on CPS acknowledges that prior knowledge, previous experience, and the problem context are important and potentially influencing factors, but neither necessary nor sufficient for CPS (Funke, 2001). Consequently, general processes taking place before a considerable amount of knowledge is gathered and before problem solvers switch to more specialized strategies are targeted. But is there empirical proof supporting the assumption of domain general skills and strategies involved in CPS? According to Novick, Hurley, and Francis (1999), domain general processes in problem solving are important because abstract representation schemas are more useful than specifically relevant example problems for understanding the structure of novel problems. These general representations are not contaminated by specific content (Holyoak, 1985). However, Klauer (1989) reminds us that the majority of mental representations are domain-specific and that it is a challenge yet unsolved to identify overarching and, thus, domain-general cognitive representations that are relevant for an entire class of problem situations. To this end, Klauer, Willmes, and Phye (2002) report mixed and somewhat inconclusive empirical evidence with regard to transfer effects of an inductive reasoning training to other domains of cognitive ability, whereas in a problem solving context Chen and Klahr (1999) show that training students in general strategies on how to conduct experiments that allow for causal inferences leads to a substantial knowledge transfer even when training and application context differ. Thus, there seem to be general mental processes such as knowledge acquisition and knowledge application involved when solving complex problems (Novick & Bassok, 2005), but to which extent and how far they actually transfer across a number of domains is yet an open question.

1.2. Components of Complex Problem Solving

Conceptually, knowledge acquisition and knowledge application are defining components that are considered to be overarching processes in CPS (Funke, 2001; Novick & Bassok, 2005), but more detailed theoretical conceptions assume additional factors describing narrow components of problem solving. More specifically, Dörner (1986) and Funke (2010) identify five characteristic features of complex problems each of which corresponds to one narrow requirement a problem solver has to meet: (1) complexity demanding reduction of information; (2) intransparency demanding the systematic generation of information; (3) interconnectedness demanding building a model of the problem; (4) dynamics demanding forecasting and controlling future developments; and (5) politely (i.e., goals may be contradictory and cannot be reached simultaneously; Funke, 2010) demanding evaluation and setting priorities (Greiff, 2012). Whereas (1) to (3) can mainly be subsumed under the first component of knowledge acquisition, (4) and (5) mainly adhere to the second component, knowledge application (Fischer, Greiff, & Funke, 2012). Importantly, the five narrow requirements associated with a complex problem have never been directly assessed in empirical research and CPS measures appear generally limited. The majority of CPS studies provide overall measures on both, knowledge acquisition and its application. If these two components are assessed separately, they are moderately related with correlations ranging from .50 to .75 (e.g., Kluge, 2008; Schweizer, Wüstenberg, & Greiff, 2013; Wüstenberg, Greiff, & Funke, 2012). For instance, in the CPS task Space Shuttle employed to a representative German sample within the Programme of International Student Assessment (PISA) survey 2000, Wirth and Klieme (2003) observe a manifest correlation of .60 between knowledge acquisition and knowledge application indicating that a correct problem representation usually but not necessarily leads to a correct solution and vice versa.

Attempts to utilize more than these two overarching components are scarce, although some studies incorporate an evaluation free exploration phase. An exploration phase is considered evaluation free if no target values are presented and, thus, exploration takes place without problem solvers simultaneously trying to reach given target values. If such a phase is implemented, problem solvers can explore the problem situation freely without trying to simultaneously reach a goal state. In doing so, individual differences in exploration strategies and in the ways problem solvers generate information become visible, allowing participants to utilize their strategic skills under standardized conditions (Wüstenberg et al., 2012). Such an evaluation-free exploration phase exists but is not scored in Bühner, Kröner, and Ziegler (2008). Greiff, Wüstenberg, and Funke (2012), however, explicitly score the exploration phase, leading to three dimensions that are related to three out of five of the requirements mentioned above (please note: (1) information reduction and (5) evaluation are not included): (2) information generation and (3) model building as subcomponents of knowledge acquisition and (4) control as a subcomponent of knowledge application. Whereas (3) and (4) are moderately to strongly related (see above), evidence supporting the relation of (2) and (3) is less clear. Studies reporting empirically separable dimensions for (2) and (3) are based on data from homogenous samples (i.e., highly selected university students), the use of which may artificially create multidimensional factor solutions. Even further, Wüstenberg et al. (2012) fail to find a 3-dimensional model because (2) systematically generating information is immediately followed by and directly leads to (3) a correct model of the underlying problem structure rendering an additional score for exploration behavior dispensable.

To this end, we anticipate finding two CPS components in our sample: (3) model building indicating the final level of knowledge acquisition and (4) control indicating the final level of knowledge application. The according 2-dimensional model is expected to show better fit than competing models.

Hypothesis 1(a). An adequate measurement model of CPS will be composed of two components, knowledge acquisition, indicated by model building, and knowledge application, indicated by control.

Hypothesis 1(b). The model in Hypothesis 1(a) will provide a better fit than either a 3-dimensional model with an additional component for generating information or a 1-dimensional model with one general CPS component only.

1.3. Issues of construct validity: Complex Problem Solving and personality

CPS unfolds and develops over the lifespan, in particular during adolescence (Frischkorn, Greiff, & Wüstenberg, in press; Molnar, Greiff, & Csapo, 2013). This development may not be independent of personality.

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