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The relations among openness, perseverance, and performance in creative problem solving: A substantive-methodological approach☆

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ABSTRACT

The present study provides a substantive-methodological perspective on students' willingness to engage in problem solving, a motivational determinant of 21st century skills. In particular, we study the usefulness of different models to describe (a) the structure of students' openness and perseverance as indicators of their willingness to engage in problem solving; (b) the measurement invariance and mean differences across three countries; and (c) the relation to students' performance in creative problem solving. Using the PISA 2012 data sets of Australia, Norway, and Singapore, we apply multi-group structural equation modeling to address our objectives. The results show that a correlated-traits–correlated-(methods-1) model represents the structure of openness and perseverance, and that scalar invariance is met. Regarding the differences in the levels of openness and perseverance across countries, we find the highest levels of perseverance in Singapore and the lowest levels in Norway. The inverse effects are present for students' openness. Moreover, we find only small cross-country differences in the relations to problem solving performance. Our findings shed light on the measurement and modeling of openness and perseverance as motivational aspects of 21st century skills.

1. Introduction

The development of students' skills is closely related to motivational factors such as interest, self-beliefs, and goal orientations (Jonassen, 2011; OECD, 2014; Wang & Eccles, 2013). Especially in the context of 21st century skills, clarifying the role of motivation and what students' drives to engage in developing these skills becomes important, since most of them have not yet been fully understood (Greiff, Holt, & Funke, 2013). Twenty-first century skills comprise different ways of thinking (creativity and innovation, critical thinking, problem solving, decision making, learning to learn, and metacognition), ways of working (communication and collaboration), tools for working (information and ICT literacy), and aspects of living in the world (global and local citizenship, life and career, personal and social responsibility, cultural awareness and competence), and are considered to be of cross-curricular nature (Binkley et al., 2012, pp. 18–19).

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One prominent 21st century skill refers to students' ability to solve complex problems that mimic real-life situations and require interactions with an unknown environment (Greiff et al., 2013; Molnár, Greiff, & Csapó, 2013). Besides solving such interactive problems, real-life situations may also represent static problems, which can be solved with the help of reasoning and connecting the information given within the problem (Scherer & Tiemann, 2014). Both the ability to solve interactive and the ability to solve static problems can be regarded as components of students' creative problem-solving competence, which plays a crucial role in the 21st century (OECD, 2013a). Since these skills require more sophisticated assessments and comprise complex combinations of abilities (Wüstenberg, Greiff, & Funke, 2012), their relation to potential determinants such as students' motivation and engagement needs to be clarified.

In the context of the Programme for International Student Assessment (PISA) in 2012, creative problem-solving skills along with their motivation and drive to learn have been assessed across more than 40 countries (OECD, 2013a, 2014). Among other constructs, students' openness and perseverance to problem solving were examined as motivational determinants of learning processes. These two constructs comprise elements that are closely related to self-beliefs, goal orientations, personality, and interest, and describe students' willingness to engage in problem solving, even when facing obstacles (OECD, 2013b). Following existing research on the positive relation of openness and perseverance to students' general cognitive abilities (e.g., Beaty, Nusbaum, & Silvia, 2014; Carr & Steele, 2009), one would expect positive relations to creative problem solving. In fact, the PISA 2012 results supported this expectation (OECD, 2013a, 2014). However, these results were based on the assumption that openness and perseverance represent distinct and unidimensional constructs. Moreover, although both constructs show a conceptual overlap, they have not yet been studied jointly and little attention has been paid to their factor structure, along with the generalizability across countries.

In light of these research gaps, the present study is aimed at investigating the structure and invariance of students' willingness to engage in creative problem solving with respect to their openness and perseverance. On the basis of the structural and invariance results, comparisons of factor means and correlations to problem solving performance across three countries are employed. We conduct multi-group structural equation modeling to the PISA 2012 data sets of Australia, Norway, and Singapore, and propose a substantive-methodological synergism.

2. Theoretical framework

2.1. Substantive focus: students' willingness to engage in problem solving

Twenty-first century skills are of particular interest in educational and psychological research, since they often require more than reasoning or the application of school knowledge (Binkley et al., 2012; Jonassen, 2011). One of the most prominent 21st century skills refers to creative problem-solving competence (Greiff et al., 2013; Molnár et al., 2013). In the PISA 2012 framework, this competence is defined as:

> [. . .] an individual's capacity to engage in cognitive processing to understand and resolve problem situations where a method of solution is not immediately obvious. It includes the willingness to engage with such situations in order to achieve one's potential as a constructive and reflective citizen. (cf. OECD, 2014, p. 40)

From a cognitive perspective, creative problem solving comprises a number of skills that determine the processes for solving different types of problems (Mayer, 1998; Scherer & Tiemann, 2014; Wüstenberg et al., 2012). In the context of the PISA 2012 framework, these skills refer to understanding, representing, planning, executing, monitoring, and reflecting the problem, and are assessed by using interactive and static problems (OECD, 2013b, 2014).[1] In solving interactive problems, it is not only required to perform the cognitive processes mentioned above, but also additional skills such as self-regulated knowledge acquisition by interacting with complex and unknown systems (Wüstenberg et al., 2012). Developing these skills is considered a crucial element of 21st century education (Binkley et al., 2012; OECD, 2013b).

Beyond mentioning cognitive processes, the definition of creative problem solving contains a motivational component (OECD, 2014). On the one hand, students' willingness to engage in problem solving is considered an *element of* their competence in problem solving, since competences generally describe the "latent cognitive and affective-motivational underpinning of domain-specific performance in varying situations" (cf. Blömeke, Gustafsson, & Shavelson, 2015, p. 3). In this sense, the measurement of creative problem solving as a competence should account for motivational aspects. Consequently, students' willingness to engage in problem solving was assessed in addition to problem solving competence in PISA 2012 but not as an integral part of the problem solving tasks (OECD, 2013a). On the other hand, some research indicates that students' willingness to engage in problem solving positively affects their performance and forms a *determinant of* initializing problem solving processes (Mayer, 1998). Thus, students' willingness is crucial for engaging and performing in problem solving, and should therefore, be studied in relation to students' actual performance. Against this background, the present study attempts to take a closer look at the willingness-performance relation.

[1] We argue that the concept of creative problem solving involves analytical and complex problem solving, since the assessments in PISA 2012 contained analytical-static and complex-interactive tasks (OECD, 2013b, 2014). For a comprehensive overview of research on analytical and complex problem solving, please refer to Funke (2010) and Greiff et al. (2013).