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Technology-based assessment of creativity in educational context: the case of divergent thinking and its relation to mathematical achievement

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ABSTRACT

Creativity is one of the most frequently cited 21st century skills, and developing creativity is one of the most often declared goals of modern education systems. However, without easy-to-use assessment instruments available for everyday application in educational practice, systematic improvement of creativity is far from a realistic option. The aim of the present study is to explore the possibility of online assessment of divergent thinking and to contribute to the development of a reliable technology-based test. The paper also investigates the relationship between divergent thinking and mathematical achievement in different dimensions. The sample for the study was drawn from sixth-grade students ($N = 1{,}984$). The computerized instrument comprising nine tasks was based on item types for divergent thinking by Torrance and by Wallach and Kogan. Our online test proved to be a reliable instrument. Based on theoretical assumptions, evidence for construct validity was provided for both the fluency–flexibility–originality and verbal–figural dimensions. Divergent thinking predicts mathematical achievement at a moderate level. The advantages of technology-based assessment made our instrument suitable for everyday school practice and large-scale assessments; however, the coding process is not yet fully automated.

1. Introduction

The significant role of creativity in the 21st century is undisputed. An ever more rapid economic, social and technological development requires new and original ideas and solutions. Creativity is indispensable for success in a wide range of jobs in modern societies (Florida, 2004) and one of the most frequently mentioned 21st century skills (Binkley et al., 2012). Twenty-first century skills are described as skills which are essential to succeed in work and life in the current century, such as critical thinking, problem solving, communication, collaboration, and information and communication technology (ICT) literacy. Creativity is interconnected to other 21st century skills: solving a problem often requires creative ideas; communicating and working creatively play an important role in successful social life; and creative usage of information and digital technologies are also essential in navigating through everyday life in the 21st century (Piirto, 2011). Thus, developing creativity is one of the most often declared goals of modern education systems (COM, 2010). From a practical perspective, one

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of the major obstacles to its development is the lack of easy-to-use instruments. Most existing tests are manually coded, and the coding process may involve subjective decisions. Their application is time-consuming and expensive. Without reliable measurement instruments, even the simplest training experiment is impossible, and a systematic development of creativity in an educational context requires routinely applicable assessment tools. The aim of the present study is to explore the possibilities for a technology-based assessment of creativity in regular schools and to contribute to the development of a reliable online instrument.

1.1. Definition and assessment of creativity: the case of divergent thinking

Although there is an agreement about the importance of creativity, there are large numbers of diverging interpretations and views about the nature of it. Due to the different perspectives and paradigms in the research on creativity, arriving at a standard definition as a construct is a challenging enterprise. However, there are common features in different definitions, and it seems there is a consensus that creative acts result in output which is novel and has some sort of value (for more about definition problems, see Piffer, 2012; Plucker, Beghetto, & Dow, 2004; Runco & Jaeger, 2012; Simonton, 2012). Although there is a sort of agreement on these characteristics, studies conducted in the field have proved that creativity is an extremely complex phenomenon and that there are many approaches to studying it (Mayer, 1999; Runco, 2007). For example, one can focus on the creative process (cognitive factors), the individual (identifying personal traits, attitudes and behavioral correlates), the product (determining what makes a product creative) or press (attributes of creativity-fostering environments) (Plucker & Renzulli, 1999). All of these approaches have different assessment methods and highlight different aspects behind creative performance; thus, the search for a single type of creativity assessment is misleading. There is no simple measurement of creativity (Funke, 2009; p. 14).

Research on divergent thinking is one of the major approaches in the identification of thinking processes behind creative performance (Runco, 2011). From an educational perspective, it has been considered an indicator of creative potential (Kim, 2006; Runco & Acar, 2012). Divergent thinking was part of Guilford's (1967) Structure of Intellect model, in which he described it as part of problem solving. Divergent thinking refers to the process of generating numerous answers or ideas for a given topic or problem. This stands in contrast to tasks that represent convergent thinking, in which only a single or a few correct solutions are possible, such as in conventional intelligence tests.

To assess divergent thinking, Guilford devised a number of tasks (Guilford, 1967), and further tests were developed based on his work which became widely used instruments in creativity research such as the Torrance Test of Creative Thinking (TTCT, Torrance, 1966) and the Wallach–Kogan Creativity Test (WKCT, Wallach & Kogan, 1965). These measurement tools usually consist of tasks with verbal- and figural-based items. In verbal-based items, both the stimuli and the responses are verbal. For example, one has to list as many unusual ways to use a book as one can think of or name all the round things. In figural-based tasks, stimuli are figural, but the response could be figural or verbal. For example, on some TTCT tasks, the respondent is expected to complete or produce drawings (figural–figural), and one has to interpret lines or figures (figural–verbal) on WKCT instances tasks. Different types of tasks may represent different ways of thinking or strategies during task completion (see Cheung & Lau 2010).

Different scales were suggested by Guilford (1967) to evaluate such tasks, like fluency, flexibility and originality. Fluency refers to the ability to produce numerous ideas for a given problem, and it is assessed by the number of interpretable, meaningful and relevant responses. Flexibility is described as the skill to see a problem from different approaches, and it is scored by the number of different categories implied by the responses. Originality refers to the ability to produce unique, unusual ideas, and it is usually measured by the statistical rarity of the responses in a given sample (e.g., answers given by less than 1 or 5% of the participants; for examples of different scoring techniques, see Runco & Acar, 2012). However, studies usually found highly positive correlations between the three indices of divergent thinking. Some psychometrics argued that fluency would be enough because the other two measures add only little information (e.g., Hargreaves & Bolton, 1972). On the other hand, others showed the factors can be separated (e.g., Dumas & Dunbar, 2014) and claimed that originality and flexibility are representing important aspects of creative thinking. Due to the debate others suggested alternative scoring methods for divergent thinking tests (Plucker, Qian, & Wang, 2011; Snyder et al., 2004).

1.2. Online assessment of divergent thinking

Technology-based assessment is one of the most rapidly developing research areas in educational practice. The growing attention can be explained by the advantages of technology-based assessment, such as online test administration, automated scoring, improved precision, objectivity, reliability and the possibility of immediate feedback (Csapó, Ainley, Bennett, Latour, & Law, 2012). In the measurement of divergent thinking, test administration and scoring are among the major concerns: open-ended tasks generate numerous responses which are difficult to process with traditional paper-and-pencil test administration. Each answer has to be coded and scored manually. Researchers have to decipher handwriting, and data has to be digitized before performing statistical analyses. Due to these aspects of paper-and-pencil test administration, the data analysis process is extremely time-consuming and cannot be implemented effectively in everyday school practice. However, technology-based assessment of divergent thinking is still in its infancy. Only a few studies have focused on the potential for technology-based assessment of divergent thinking (Cheung & Lau 2010; Kwon, Goetz, & Zellner, 1998; Lau & Cheung, 2010; Palaniappan, 2012; Pretz and Link, 2008; Rosen & Tager, 2013; Villalba, 2009). Palaniappan (2012) developed an intel-