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Objective measure of scientific creativity: Psychometric validity of the Creative Scientific Ability Test

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ABSTRACT

This article presents an overview of a new test of scientific creativity, "the Creative Scientific Ability Test (C-SAT)" and research carried out on its psychometric properties. The C-SAT measures potential for scientific creativity with fluency, flexibility and creativity components in hypothesis generation, experiment design and evidence evaluation tasks in five areas of science. In the current study, the test was administered to 693 sixth-grade students. The internal consistency reliability was found to be good (.87) and the interscorer reliability was excellent (.92). The Confirmatory Factor Analysis confirmed the one-factor model solution for the C-SAT scores. The test had medium to high-medium correlations with math and science grades and a mathematical ability test. Mathematically talented students scored higher on the C-SAT than did average students. Research findings show that the C-SAT can be used as an objective measure of scientific creativity both in research and in the identification of scientifically creative students.

1. Introduction

The idea of novelty along with relevance, effectiveness, importance, and surprise is central to the definition of creativity. Aligned with this idea, creativity usually is defined as the ability to generate ideas or products that are novel and useful (Boden, 2004; Cropley, 1999; Mayer, 1999; Piffer, 2012; Plucker, Beghetto, & Dow, 2004; Sak, 2004; Sternberg & Lubart, 1995). We like to present, at the outset, our definition of scientific creativity that has led our work on the Creative Scientific Ability Test (C-SAT). Our definition is inspired by general definitions of creativity. Scientific creativity may be defined as the ability to generate novel ideas or products that are relevant to context and have scientific usefulness or importance. According to this definition, any scientific idea that is extremely original but does not fit the context or is not useful at all cannot be considered to be creative. Thus, any scientific idea to be accepted as creative needs to present some degree of originality and usefulness. The degree of originality and usefulness determines the level of creativity of the idea.

The two constructs, scientific creativity and general creativity, have both similarities and differences. As the above definitions show, both processes should result in novelty and usefulness in products to be accepted as creative. That is, the definitions of the both construct largely overlap. However, the two constructs differ in their theoretical foundations. The main difference between the two construct are the knowledge component and domain-relevant skills. In the process of general creativity, commonsense knowledge which is simple, general and relatively unstructured plays a major role. In contrast, in domain specific creativity, domain specific and technical knowledge is the foundation of creativity. In addition to

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usefulness and novelty in science, new ideas should be consistent with the existing knowledge. Eminent physicist Feynman, for example, claims that whatever we are allowed to create in science must be consistent with everything else we know. The problem of creating something new and consistent with everything is one of extreme difficulty" (Feynman, Leighton, & Sands, 1964 as cited in Tweney, 1996). Furthermore, creativity is accepted to be domain general for everyday skills and develops into domain specific forms upon the acquisition and utilization of domain relevant skills and knowledge (Amabile, 1983; Kaufman & Baer, 2005; Plucker & Beghetto, 2004). Therefore, scientific creativity can be conceptualized as a domain specific form of general creativity.

In this article, we, first, discuss the need for a domain-specific test of scientific creativity and the construct of scientific creativity, and then the C-SAT for measuring scientific creativity followed by research carried out on its validity. The C-SAT was developed based on a theoretical framework (Sak & Ayas, 2013), using the Scientific Discovery as a Dual Search model proposed by Klahr and Dunbar (1988) and Klahr (2000) and research in the assessment of general creativity. The model consists of both domain-specific creativity skills and content-general creativity skills. We limited the number of skills used in the framework to the theoretically most important ones; otherwise, the assessment of scientific creativity would be practically impossible; because, both general creativity and scientific creativity involve many thinking and problem solving processes.

2. The need for domain-specific tests of creativity

Research on the assessment of creativity has been criticized for using creativity tests that have trivial and theoretically too general items to measure such a multidimensional construct (Baer, 1994; Frederiksen & Ward, 1978; Hocevar, 1979a; Kaufman, Plucker, & Baer, 2008). The evidence for domain specificity of creativity is found both in broadly defined cognitive domains (e.g., mathematical, linguistic, and musical) and in narrowly defined tasks or content domains (e.g., poetry writing, story writing, and collage making) (Baer, 1998). In some studies, even in the same domain, microdomain differences also were found in creativity assessments (Baer, 1991, 1993, 1994; Runco, 1989). In their construct validity study of the Torrance Test of Creative Thinking, for example, Almeida, Prieto, Ferrando, Oliveira, and Ferrandiz (2008) found that specificity of demands in each task was better identifiers than cognitive processes related to creativity. Baer (1994) and Kaufman et al. (2008) further criticized the inefficiency of general creativity tests in predicting real-life creativity and suggested the use of domain-specific tests of creative ability. Baer (1991, 1993), for example, carried out a series of research to investigate generality and specificity of creativity, using poems, stories, equations, mathematical word problems and collages tasks. The results of these studies showed a range of correlations from −0.05 to 0.08, supporting a task-specific view of creativity.

The domain generality and specificity of creativity also can be a result of assessment types used to measure creativity. Plucker (1998) and Runco (1987), for example, argued that performance assessments produce evidence of task specificity while creativity checklists and similar assessments suggest evidence of general creativity. Likewise, Kaufman and Baer (2002) used the term "garden-variety" creativity to highlight research findings that self-report and personality studies suggest domain general factors that influence creative performance in all domains, whereas performance assessments of creativity in different domains indicate little or no evidence of general factors. After reviewing studies regarding content generality and task specificity of creativity, Kaufman and Baer concluded that the evidence for general creativity-relevant skills is rather weak.

Supporting the idea for domain-specific assessment of creativity, Frederiksen and Ward (1978) and Hu and Adey (2002) developed prototype tests of scientific creativity as criterion measures of scientific creativity. Both tests were found to have satisfactory reliability and validity evidences in preliminary studies. Frederiksen and Ward used the situational tests approach, using important aspects of the job of a scientist, such as formulating hypotheses and evaluating proposals. Hu and Adey applied a different approach and used the Scientific Structure Creativity Model in their studies to develop the scientific creativity test for secondary school students. The model includes both general creativity skills, such as fluency and flexibility and science-related skills, such as imagination and thinking. Although this model has a strong theoretical background in general creativity, its theoretical framework lacks a theory of scientific creativity. For example, imagination and thinking are used in all kinds of creativity and thinking is a very general psychological process that needs to be specified in psychological measurements. Also, as the both tests were prototypes, further studies were also needed in order for these tests to be used in studies and identification practices. No such studies have been reported. The C-SAT differs from the both tests in terms of its theoretical background and the scoring method as discussed later.

3. Scientific creativity

Scientific creativity is viewed as a result of a convergence of a number of cognitive and noncognitive variables, such as intelligence, creativity-related skills, science-related skills, personality characteristics and motivation, interest, concentration and search for knowledge and chance permutation of mental elements (Dunbar, 1999; Heller, 2007; Klahr, 2000; Puccio, 1991; Roe, 1952, 1961; Simonton, 1988; Subotnik, 1993; Torrance, 1992). Some researchers even used the term of scientific giftedness along with scientific creativity (Innamorato, 1998; Shim & Kim, 2003). Scientific giftedness can be thought of as a domain-specific form of giftedness like other forms of domain-specific giftedness, such as mathematical giftedness, and giftedness in music and the arts. Emerging conceptions of giftedness also support the construct of domain-specific giftedness (see Conceptions of giftedness, Sternberg & Davidson, 2004). Gardner (1999), for example, postulated the existence of