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Creativity of gifted students in an integrated math-science instruction

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ABSTRACT

This study designed and applied integrated math-science instruction to gifted students to enable expression of creative potential, and examined the creativity and creative productivity in the context of a classroom designed to facilitate improvement. Study participants consisted of 20 mathematically gifted elementary students in a combined 5-6th grade class operated by a university affiliated institute for gifted students in Seoul, South Korea. Gifted students that received 8 sessions of integrated instruction did not think of math and science concepts separately but designed the solution process appropriately and solved problems creatively. Creativity tests showed a high correlation between subcomponents, and assessment scores on productivity using a gear Goldberg machine showed that divergent thinking and originality have a significant effect on the production process.

1. Introduction

The future is difficult to predict in an environment of rapid change, depleted resources, and new information technology. The goal of education is to help prepare the next generation to confront real life situations through imagination, as significant achievements were historically accomplished by men with creative tendencies rather than simple intelligence. Studies have suggested that creativity is a key component of giftedness and the assessment of giftedness should take creativity into account (Renzulli, 1978; Sternberg and Lubart, 1993, 2004).

Countries invest heavily in developing superior human resources, with a special interest in gifted education to take the lead in the global economy. However, practical curriculum for gifted children is insufficient in the discussion of gifted education, and the debate on acceleration and advanced education is abundant (VanTassel-Baska, 1986). Giftedness and creativity can be better developed when integrated into lessons taught in classrooms rather than taught as separate skills. As students spend a lot of time at school and attempt to share ideas in class, creativity can be maximized when both the educational environment and the teacher support creativity. Therefore, studies that explore the relationship between classroom and creativity are needed to remove obstacles and include creativity-oriented curriculum (Beghetto, 2010).

This study attempted to design and apply integrated math-science instruction to gifted elementary children and examine the creative potentials and productivities expressed in the process. The following research questions guided this study:

1. How are gifted students' creativity and creative productivity in math-science integrated instruction?
2. How are creativity and creative productivity of gifted students related?

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1.1. Gifted students and integrated instruction

Science, technology, engineering and mathematics (STEM) is curriculum introduced by the U.S. National Science Foundation that integrates the aforementioned subjects and has expanded to include psychology, sociology, economy, and politics. STEM is an educational program designed to increase science and math aptitude and foster talent in students that may become scientists and engineers working on a global scale. Some states have created STEM schools at the elementary and secondary levels (Breiner, Harkness, Johnson, & Koehler, 2012). According to a report from The President's Council of Advisors on Science and Technology (PCAST, 2010) in the U.S., STEM education is an important goal that can decide whether the U.S. will remain a world leader and solve enormous challenges of the future. Yakman (2008) proposed STEAM, an integrated educational measure designed to combine art education with STEM.

Gifted children need to be provided with an educational experience that is differentiated and relevant, requiring the development of effective curriculum and a specialized instructional model. However, there has been little research on curriculum in the field of gifted education (VanTassel-Baska, 1986). To increase the level of creativity and achievement by gifted children, research is needed on curriculum that takes their individual characteristics into account. Research on applying STEAM education has been conducted in Korea. STEAM education is an appropriate educational model for gifted children, allowing them to broaden interests and curiosity, seek solutions, and explore reasoning and phenomena by thinking and acting creatively (Lee, Baek, & Lee, 2013; Lee, Suh, Jung, Kang, & Lee, 2012). Development principles of organizing differentiated curriculum include nurturing active self-directed learners, fostering the spirit of challenge and experimentation, and enhancing cooperative capacity when integrated education is applied to gifted education (Song, Moon, Hah, Han, & Sung, 2010). STEM can be a cross-disciplinary and interdisciplinary tool used by gifted children to compete in a fierce global economy and to search for new solutions (Roman, 2012). Further, teachers play a key role in including more integration of mathematics and science curricula in instruction, and positively impacting the lives and careers of the next generation (Furner & Kumar, 2007).

1.2. Giftedness and creativity

Creativity is defined in a number of ways by scholars, including the capacity to produce ideas related to divergent thinking rather than convergent thinking (Guilford, 1959); new and appropriate ideas, behaviors, and products (Amabile, 1982); and new and valuable ideas or behaviors generated from interaction between a person's thinking and socio-cultural context (Csikszentmihalyi, 1996). Most researchers agree on a general definition of creativity as "the ability to produce a new, high quality, and appropriate product" (Sternberg, Kaufman, & Pretz, 2002). Creativity could be seen from the process of problem solving attaching importance to the process of problem solving, and a recent study went further that creativity should be developed in the process of solving the problem of a real world (Basadur, Gelade, & Basadur, 2014) As such, most researchers mentioned that there was a similarity between creativity and problem solving and creativity could be developed better in a real world problem.

Gifted education takes a special interest in creativity and regards it as a factor that explains the characteristics of a gifted child (Renzulli, 1978). It has a major influence on gifted children's achievement to prompt their creativity in an appropriate time (Gowan, 1980). Meador (2003) stated that education designed for gifted children can combine creative thinking skills with instruction that encourages encounters with complex phenomena. Sternberg and Lubart (1993) argued that a program designed for the development of creative children should be based on creativity that includes cognitions, thinking types, personalities, and motivations different from academic giftedness and creative performance different from academic performance.

There are literatures about how creativity works in the process of solving the mathematical and scientific problems. Aiken (1973) explained mathematical creativity as differentiating between the 'process,' which is the ability to analyze a problem, find patterns, and see the similarities and differences; and the 'product,' which is the ability to find solutions applicable to the problem. Mann (2005) stated that the quantitative assessment of mathematical creativity applies the concepts of flexibility, fluency, and originality to students' answers. Meissner (2006) viewed development of mathematical creativity as requiring individual and social orientation, a challenging problem, and problem solving skills. Sak and Maker (2006) suggested that creative mathematical thinking could be possible with lots of mathematical knowledge, Mann (2005) and Tabach and Friedlander (2013) said that mathematical creativity could be developed with more mathematical knowledge.

Heller (2007) regarded a scientific creativity as an individual and social ability of solving the complex scientific problems in a progressive way, and Stumpf (1995) related scientific creativity to having a sparking idea during problem-finding, expanding the exploration, and elaborating the problem solution. It is important to make a new solution from collecting the related information and combining them in the scientific problem solving process (Mumford, Hester, & Robledo, 2010). Meador (2003) said that a creative scientist had a difference in flexibility and openness about experiences, and proposed that the instructional environment should emphasized the process of thinking creatively and discussing freely to bring gifted children up to be a creative scientist.

In summary, creativity in mathematics and science is the ability to solve a given problem in a new way by applying facts, concepts, principles, and thinking strategies that students already possess. In the same way creativity is regarded as a process to produce something new and useful on the basis of individual and group characteristics (cognitive and affective