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CREATIVE THINKING IN MATHEMATICS: ARE WE ABLE TO SOLVE MATHEMATICAL PROBLEMS IN A VARIETY OF WAY?

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ABSTRACT

Creative thinking is very important in this era of global competition, since the level of complexity problems is higher in all aspects of modern life. In creative thinking, two parts of the brain is needed. The balance between logic and intuition is essential. What is creative thinking? What is the essence of creative thinking? What competencies are required to assess creative thinking ability? What are the characteristics of mathematical problems that can be used in creative thinking? The answers to these questions are the focus of this paper.

Keywords: Creative Thinking, Mathematical Problems

INTRODUCTION

Creativity is a complex construct and is most commonly expressed through a broad range of intelligences including linguistic, musical, mathematical, spatial, kinesthetic, interpersonal, and perhaps even intrapersonal (Gardner, 1985). In an operationally problem-oriented definition, Torrance (1966) defined creativity as a process of becoming sensitive to a problem, deficiencies, gaps in knowledge, missing elements, disharmonies, and so on; identifying the difficulty; searching for solutions, making guesses, or formulating hypothesis about these deficiencies; testing and retesting these hypotheses and possibly modifying and retesting them; and finally communicating the results. This creativity will arise if someone can do creative thinking.

Creative thinking is very important in this era of global competition, since the level of complexity problems is higher in all aspects of modern life. In creative thinking, two parts of the brain is needed. The balance between logic and intuition is essential. If someone has an ability to think creatively, then they can solve their problems in a real life with a variety of possible ways they can do. Pay attention to the importance of creative thinking, therefore the authors try to explain about creative thinking.

Creative thinking that discussed in this paper is focused on creative thinking in mathematics. The author is interested to explain about creative thinking in mathematics because many students are still difficulties in solving mathematical problems in a variety of way. Through an explanation of creative thinking in this paper, readers are expected can find out the definition of creative thinking and the essence of creative thinking. More than that, readers can find out the competencies are required to assess creative thinking ability and characteristic of mathematical problems that can be used in creative thinking.

CREATIVE THINKING IS DEFINED

Thinking is a mental activity that is experienced by a person when they encounter a problem or situation that must be solved. Suryabrata (1990) believes that thinking is a dynamic process that can be illustrated according to the process and the course. The thinking process essentially consists of three steps that are the formation of understanding, opinion formation, and making conclusions. This view shows that in thinking a person must understand first the problem or situation that available in some definitions. Then that person compiled the opinions. After that, he will make a conclusion and searching for the right solution of the problem.

Thinking as a person's mental abilities can be divided into several types, such as logical thinking, analytical, systematic, critical, and creative. Logical thinking can be defined as the student's thinking ability to create legal conclusions according to the rules of logic

and can prove that the conclusions is true or valid according to the previous knowledge that is already known. Analytical thinking is the student's thinking ability to elaborate, specify, and analyze information that used to understand the knowledge by reasoning and thinking logically, not based on feelings or guesses. Systematic thinking is the student's thinking ability to work or complete tasks according to sequence of stages, steps, or right planning, effective, and efficient. The three types of thinking are connected. Meanwhile, critical thinking and creative thinking is a manifestation of higher order thinking. Critical thinking can be seen as the ability to think students to compare two or more information. Critical thinking is often associated to creative thinking (Siswono, 2008).

Csikszentmihalyi (1997) define creative thinking is generating new ideas within or across domains of knowledge, drawing upon or intentionally breaking with established symbolic rules and procedures. In the context of college teaching and learning, creative thinking deliberately and actively engages students in bringing together existing ideas into new configurations, developing new properties or possibilities for something that already exists, and discovering or imagining something entirely new. Creative behaviours include: analyzing and evaluating information/context in order to frame the problem scope, synthesizing information and generating multiple solutions to the problem, exercising insight about alternatives and choosing a solution, evaluating the worth and consequences of an implemented solution, and elaborating. Based on this definition, creative thinking is a way to generate new ideas by using creative behaviours. Trough the creative behaviours, students can be active and creative in class. They can use their creative thinking to solve the problems in any variety of way. So, the problems must have a multiple solution.

According to Bishop, one needs two very different complementary modes of thinking in mathematics: creative thinking, for which "intuition" is typical, and analytic thinking, for which "logic" is typical (Pehkonen, 1997). This view shows that creative thinking is not based on logical thinking, but more as a thought that suddenly appeared, unexpected, and unusual. On the other hand, Pehkonen (1997) say that creative thinking might be defined as a combination of logical thinking and divergent thinking which is based on intuition but has a conscious aim. When one is applying creative thinking in a practical problem solving situation, divergent thinking produces many ideas. Some of these seem to be useful for finding solutions. This understanding explains that creative thinking requires a logical and intuitive thinking to generate ideas. Hence, in creative thinking, two parts of the brain is needed. The balance between logic and intuition is essential. When placing is too much logic, the creative ideas will be ignored. Therefore, for creative thinking is needed the freedom of thought, is not under the control or pressure.

The tendency of people who believe that mathematics does not have the same characteristics with creativity can be seen from the view that generally people do not see any real products mathematics that categorized as creative. Contrary to this, Worthington (2006) believes that students need to go beyond making things, products, and develop creative mathematical thinking and problem solving or processes. Through this way, we will be helping them build strong foundations for learning mathematics. Talking creativity in mathematics is more focused on aspects of the process, namely the process of creative thinking. This argument explain that creativity in mathematics more precise be termed as mathematical creative thinking. However, in this paper the term of creativity in mathematics and mathematical creative thinking commonly used alternately.

THE ESSENCE OF CREATIVE THINKING

Mahmudi (2008) reveals that the competitive power of a nation is determined by the creativity of its human resources. Creativity is needed in every aspects of life. He needed to design something, improve quality of life, creative changes, and solve problems. In this context, creativity becomes a prerequisite for individuals to solve the problem. This opinion explains that creative thinking is very important in life and determining excellence or competitive power of nation. With creative thinking, we can produce a creativity that we can use to design something, improve quality of life, creative changes, and solve the problem.

Creativity is also a prerequisite for the success of the individual life. According to Alexander (2007), the success of an individual life is determined by its ability to creatively solve problems, both large and small scale. Creative individuals can view a problem from different perspectives. This point of view allows the individual to obtain a variety of appropriate alternative solutions to resolve the problem.

Career Center Maine Department of Labor (2004) give information that today's work competencies are

1. Self-Esteem
   Belief in your own selfworth and abilities.
2. Motivation to Achieve
   The desire to improve performance by competing against increasingly higher standards of excellence.
3. Basic Skills

Reading, writing, computation, listening, speaking and computer literacy that are essential for successful performance as lifelong learners in the workplace

4. Technical Knowledge and Skills for Specific Occupation Knowledge, skills & abilities that are necessary to perform a job
5. Thinking Skills:
   - *Problem Posing*-Choosing how to view a problem
   - *Problem Solving*-Ability to resolve known problems
   - *Decision Making*-Ability to choose a best response
   - *Analytical Thinking*-Analysis and logical reasoning
   - *Creative Thinking*-Ability to create novel ideas or products
6. Learning Skills
   Assessing your learning needs, understanding your learning styles, using appropriate techniques for learning
7. Interpersonal Skills:
   - *Interpersonal Understanding* - Hearing and understanding others' spoken, unspoken or partly expressed thoughts, feelings or concerns
   - *Teamwork* - Working cooperatively with others to achieve a common goal
   - *Negotiating* - Overcoming disagreements by compromising, accommodating, or collaborating with others
8. Organizational Awareness Skills:
   - *Assessment of Organizational Cultures* - Recognizing and assessing the characteristics of an organization's culture, including formal and informal power structures
   - *Presentation of Appropriate Self* - Developing and presenting an image of yourself which is consistent with the organization's requirements for success, including personal appearance and use of appropriate language for the corporate culture
   - *Networking* – Developing and maintaining a network of contacts with people who may be able to provide information, assistance, or support for work-related goals.

Based on that information, we know that thinking skills are very important in today's workplace. We need to be able to figure out what a problem is (problem-posing) and to know how to solve problems right the first time. We also need to learn from our mistakes and from what doesn't work. Skilled workers make good decisions using a variety of decision making styles. They also are creative on the job. Creative thinking includes how to do something faster, make something better or save the company money without compromising quality.

Kiesswetter states that, in his own experience, flexible thinking which one component of creativity is one of the most important abilities, perhaps the most important which a successful problem solver ought to have (Pehkonen, 1997). This opinion confirms the importance of creative thinking in mathematics. One of the components of creative thinking that is flexibility allowing students to use their creative ideas to solve problem in any variety of ways. They are not glued to a rule or formulas that have been assigned.

So importance the creativity in various fields requires all parties, including educational institutions, to develop it. According to Mann (2005), today, more than ever, the demand for educational institutions to prepare their graduates to be able to develop their creativity is becoming more prominent. Developing the creativity by educational institutions also expressed by the United States Department of Labor (Berg, 1999) that expects educational institutions provide the opportunity for students to construct their knowledge through creative problem solving activities related to the real problem. Strictly speaking, McBeath (McGregor, 2007) also states that educational institutions should emphasize on student's mastery of a variety of thinking skills such as critical thinking, creative thinking, and problem solving skills.

Explicitly, the mindset of the curriculum in 2013 requires process of learning and assessment should also encourage creativity. It is clear that creative thinking in producing creativity is essential in learning process. Creativity's ability in learning can be obtained by observing, questioning, experimenting, associating, and networking. Teachers need to create students creative thinking by.

1. Giving tasks that have any variety answer.
2. Tolerating unusual answer
3. Emphasizing on the process not the result
4. Encouraging students to try and determine its own interpretation of knowledge
5. Providing a balance between structured and spontaneous activity

COMPETENCIES IN CREATIVE THINKING

According to Worthington (2006), to measure student's creative thinking ability can be done by exploring the work of students that represent the creative thinking process. Meanwhile, according to McGregor (2007), to measure students' ability to think creatively can be done by grounding on what students communicated, verbally and in writing. What is student

communicated in the form of student's work related tasks, problem solving, or oral answers to the teacher questions.

Some experts have developed an instrument to measure the mathematical creative thinking abilities, such as Balka and Torrance (Silver, 1997). Torrance developed the Torrance Tests of Creative Thinking (TTCT) and Balka developed the Creative Mathematical Ability Test (CAMT). Both of these instruments create the task a math problem based on the information contained in the related matter of everyday situations that given.

The Torrance Tests of Creative Thinking (TTCT) have frequently been used to assess the creative thinking of children and adults. An extensive program of research has validated this instrument as a predictor of creative production. Three key competencies of creativity assessed by the TTCT are fluency, flexibility and novelty. Fluency refers to the *number* of ideas generated in response to a prompt; flexibility to apparent *shifts in approaches* taken when generating responses to a prompt; and novelty to the *originality* of the ideas generated in response to a prompt (Silver, 1997). Apabila kita menggunakan TTCT, maka kita membutuhkan tiga kompetensi yang harus dinilai dalam kemampuan berpikir kreatif, yaitu fluency, flexibility and novelty.

The notions of fluency, flexibility and novelty were adapted and applied in the domain of mathematics by Balka (Silver, 1997), who asked subjects to pose mathematical problems that could be answered on the basis of information provided in a set of stories about real world situations. In his analysis of students' responses, fluency referred to the number of problems posed or questions is generated, flexibility to the number of different categories of problems generated, and originality to how rare the response was in the set of all responses.

Livne and Livne developed the Multiscale Academic and Creative Abilities in Mathematics (MACAM) instrument, drawing on the framework of Milgram's 4x4 Structure of Giftedness Model. This model contains four levels of giftedness (profound, moderate, mild, and nongifted), and four ability types (general intelligence, specific academic ability, general original=creativity thinking, and specific creative ability). The testing was conducted with a nationally stratified sample in Israel and provides support for a bidimensional conception of giftedness in mathematics; one academic and one creative (Mann, 2009).

Lee et al. (2003) measured student creativity in solving open-ended mathematical problems using the Mathematical Creative Problem Solving Ability Test (MCPSAT) assessing the flexibility, fluency, and originality of the responses. The focus of the study was on finding ways to develop mathematical creativity, rather than to identify creative potential. Based on their findings, Lee et al. recommended the use of the MCPSAT as a tool to stimulate creativity and divergent thinking in mathematics, along with the inclusion of more open-ended problems in the general curriculum. As with other measures of creativity, scoring of the MCPSAT is time consuming.

Based on some of the above explanation, the authors tried to conclude some competencies that are used to assess the ability of creative thinking, that is.

1. fluency, includes solve the problem and give a lot of answers to the problem or provide many examples or statements related mathematical situation.
2. flexibility, includes the ability to use a variety of problem-solving strategies.
3. originality, includes using strategies that are new, unique, or unusual to solve problem.
4. elaboration, including the ability to explain in detail.

MATHEMATICAL PROBLEMS FOR CREATIVE THINKING

Hashimoto (1997), said that the types of problem that have potential to develop student's creative thinking ability is open ended problems. Open ended problems encourage students to creatively explore various ways or solutions of the problems. This is similar with opinion of Becker and Shimada (Livne, 2008), where an open ended problem is problem that has a variety of answers. Another way to measure creative thinking ability in mathematics is problem posing method, that is making problems, questions, or statements related to problems or situations in mathematical. Both methods are used to measure aspects of mathematical creative thinking abilities that are fluency, flexibility, originality, and detail (Mahmudi, 2008).

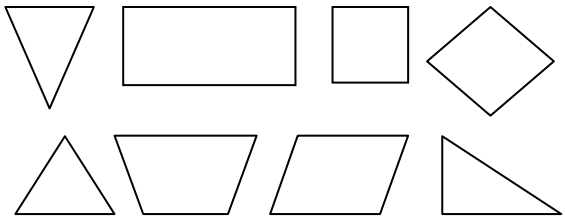
Siswono (2008) suggests criteria for tasks that can be used to explore aspects of creative thinking, such as.

1. Have the form problem solving and problem posing
2. Divergent in answers and ways of solving, so that raises the criteria of flexibility, originality, and fluency.
3. Associated with more than one mathematics knowledge/concepts of material that given to students before.
4. Information should be easily and clearly understood and captured the meaning, does not have double

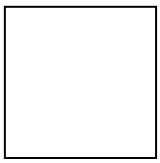
interpretation and construction of a sentence using Indonesian rules is good and right.

Based on the above criteria, the following are some examples of mathematical problems that can be used to measure student's creative thinking ability.

1. Classify the following pictures according to similarity properties that you can identify!

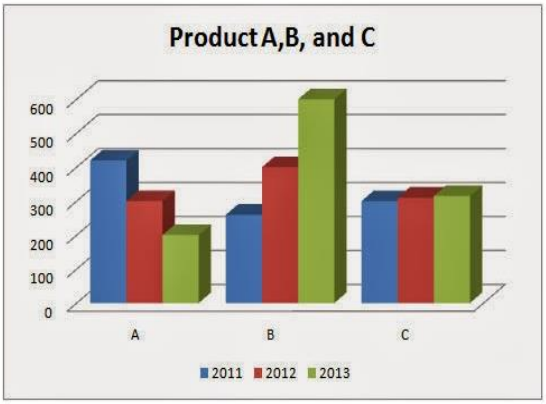


2. Given a square image as below!



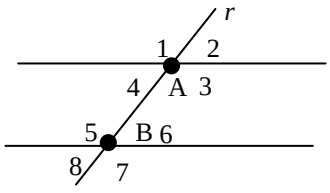
   a. Draw a quadrilateral which has same area with the image above!
   b. Show the different ways to draw that picture!
   c. Create at least two different questions related to square and solve it!
   d. From the questions that you created, is there more one than one solution? If there is, show the different answers! If there isn't, create another questions that the solutions more than one!

3. The following diagram shows the amount of products A, B, and C!



   Based on the diagram above, create 3 different problems or questions related to the topic of fractions!

4. Look at the picture below!



   a. If $\angle B_6 = 75^0$, determined $\angle A_1$ and $\angle A_4$!
   b. Can you find another ways to get that angle? Write!
   c. Make another questions that same with this topic and solve it!

CONCLUSION

The paper has discussed the issue of creative thinking in the light of what creative thinking is and the essence of creative thinking. It also discusses the competencies that people need to assess creative thinking ability and the characteristics of mathematical problems that can be used to improve creative thinking. There are four competencies to assess creative thinking, such as fluency, flexibility, originality, and elaboration. Open ended problems and problem posing are presented can influence the capability of creative thinking's children in mathematics.

REFERENCES

Alexander, K. L. 2007. *Effects Instruction in Creative Problem Solving on Cognition, Creativity, and Satisfaction among Ninth Grade Students in an Introduction to World Agricultural Science and Technology Course*. Disertasi pada *Texas Tech University*. [Online]. Tersedia:http://etd.lib.ttu.edu/theses/available/etd-01292007-144648/unrestricted/Alexander_Kim_Dissertation.pdf. [23 Agustus 2014].

Berg, R. A. 2001. *Social Constructions of Creativity in a Middle School Math Classroom*. [Online]. Tersedia: http://www.jrrb.com/examples/Social_Const_Creativity.pdf. [23 Agustus 2014].

Career Center Maine Departmeny of Labor. 2001. *Today's Work Comepetence in Maine*. [Online]. Tersedia: http://mainegov-images.informe.org/labor/lmis/pdf/EssentialWorkCompetencies.pdf. [23 Agustus 2014].

Csikszentmihalyi, M. 1997. *Creativity: Flow and the psychology of discovery and invention.* New York, NY: Harper Collins Publishers.

Gardner, H. 1985. Frames of mind: The theory of multiple intelligences. New York: Basic Books.

Hashimoto, Y. 1997. The Methods of Fostering Creativity through Mathematical Problem Solving. *Zentralblatt für Didaktik der Mathematik (ZDM)–The International Journal on Mathematics Education*. [Online]. Tersedia: http://www.emis.de/journals/ZDM/zdm973a5.pdf. [23 Agustus 2014].

Lee, K. S., Hwang, D., & Seo, J. J. 2003. A development of the test for mathematical creative problem solving ability. *Journal of the Korea Society of Mathematical Education Series D: Research in Mathematical Education*, 7, 163–189.

Livne, N.L. 2008. *Enhanching Mathematical Creativity through Multiple Solution to Open-Ended Problems Online*. [Online]. Tersedia: http://www.iste.org/Content/NavigationMenu/Research/NECC_Research_Paper_Archives/NECC2008/Livne.pdf. [23 Agustus 2014].

Mahmudi, A. 2008. Pemecahan Masalah dan Berpikir Kreatif. *Makalah*. Disampaikan Pada Konferensi Nasional Matematika (KNM) XIV Universitas Sriwijaya Palembang, 24 – 27 Juli 2008.

Mann, E. L. 2005. *Mathematical Creativity and School Mathematics: Indicators of Mathematical Creativity in Middle School Students*. Disertasi University of Connectitut. [Online]. Tersedia: http://www.gifted.uconn.edu/siegle/Dissertations/Eric%20Mann.pdf". [23 Agustus 2014].

Mann, E.L. 2009. The Search for Mathematical Creativity: Identifying Creative Potential in Middle School Students. *Creativity Research Journal*, 21(4), 338–348. Taylor & Francis Group, LLC. ISSN: 1040-0419.

McGregor, D. 2007. *Developing Thinking Developing Learning*. Poland: Open University Press.

Pehkonen, E. 1997. Fostering of Mathematical Creativity. *ZDM International Reviews on Mathematical Education*. Volume 29 No. 3 ISSN 1615-679X.

Silver, E. A. 1997. Fostering Creativity through Instruction Rich in Mathematical Problem Solving and Thinking in Problem Posing. *ZDM International Reviews on Mathematical Education.* Volum 29 No. 3 ISSN 1615-679X.

Siswono, T. Y. E. 2008. *Model Pembelajaran Matematika Berbasis Pengajuann dan Pemecahan Masalah untuk Meningkatkan Kemampuan Berpikir Kreatif*. Surabaya: Unesa University Press.

Suryabrata, S. 1990. *Psikologi Pendidikan*. Jakarta: CV Rajawali.

Torrance, E. P. 1966. *Rationale of the Torrance tests of creative thinking ability*. In Torrance, E. P. and W. F. White (eds.). 1969. Issues and advances in education psychology. Istica, IL: F. E. Peacock.