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CONVERGENT AND DIVERGENT WAYS OF THINKING IN PROBLEM SOLVING: A CASE STUDY ON JUNIOR HIGH SCHOOL STUDENTS

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Abstract

High order thinking skills (HOTS) now becomes an important skill that the students have to learn. This is because HOTS can boost the students' creativity in problem-solving in mathematics. Dealing with a creative way of thinking, there are at least two big categories, namely convergent and divergent. Several previous studies have revealed the power of the divergent way of thinking in problem-solving; however, the use of convergent way of thinking has been overlooked. Hence, the present study investigates the students' creativity in thinking from both convergent and divergent ways. At the initial stage, this case study involving 38 Junior High School students categorizes the research participants into high achievers (12), moderate achievers (18), and low achievers (8). The researcher, then, assigns the students to do four different tests, and based on the students' answers on the tests, the findings show that there are diversities which can be classified into four categories, i.e., no meaningful change (24.6%), blind variability (18.4%), orthodoxy (36.8%), and creativity (20.2%). Even though the ones belong to "creativity" is not that high compared to the ones in "orthodoxy and no meaningful change," there are interesting insights that can be obtained from the way the students solve the problems in mathematics.

Keywords: Problem Solving, Convergent Thinking, Divergent Thinking, Creativity, Four-quadrant Model

Creativity is one of the essential skills in the twenty-first century and recognized as a necessary thing for the success of the individual and the social. Although creativity is considered something important in education, the discussion of creativity in mathematics curriculum varies from country to country to another. In some countries, such as Korea, Singapore, and the United Kingdom, creativity is explicitly addressed in the curriculum of mathematics. In other countries, such as Australia, the United States, including Indonesia (Siswono, 2011) creativity is not explicitly highlighted in mathematics curriculum but the elements associated with creativity, such as fluency, flexibility, and novelty in troubleshooting or conceptual understanding, attempted. Researchers in different parts of the world have indicated that because of the environment that is driven by exams, the teachers feel overburdened when asked to apply the education of creativity in the classroom or apply it only superficially although they are interested in ideas of creativity that.

In addition to the educational problem based exams, the reluctance of teachers of mathematics or the implementation of creative learning has been identified related to the lack of a deep understanding of mathematics, knowledge and experience of teachers who lack adequate in the design of tasks or modify the task to teach creativity, and lack of awareness and a negative disposition toward creativity. Also, avoid teaching creativity associated with the conflict between the creativity of teaching and teaching skills and seems contrary to the purpose of the learning of teachers and their actions in the classroom.

Therefore, the required effort increases in-depth knowledge of teachers in mathematics, competence in the design of tasks or modify the task of creativity, awareness and a positive disposition towards creativity, education and the ability to combine the creativity of teaching and teaching skills. Creativity is closely related to creative thinking (creative thinking). Creativity is one of human intellectual knowledge often associated with problem-solving skills (Kahvecil & Akgul, 2016; Lin, 2017; Mastuti et al., 2016). Akgul & Kahvecil (2016) said that the development of the scale of creativity mathematics should pay attention to the intelligence of the students because the math is creativity intimately connected with the intelligence of students. This is corroborated by the opinion of Lin (2017) that students with a high level of ability get higher scores on creative problem-solving mathematics significantly from students with the ability of medium and low. Lin further added that the right device development and balanced in all aspects of creativity are significant in maintaining the child's creativity. Mastuti (2016) in his study of the interpretation of consciousness creativity high school teacher found that factors that may inhibit the creativity of teachers to encourage students ' creativity, among others; lack of trust teachers to students, time limitations for realization of students ' ability in problem solving, internal and external teacher activity that requires a lot of study time. Therefore creativity must also be possessed by the teachers to encourage creative students in solving math problems.

Even though there is a debate about definitions of creativity in mathematics (Sriraman et al. 2011), in general, creativity can be viewed as the confluence of divergent thinking (DT), and convergent thinking (CT) (Cropley 2006; Tan and Sriraman 2017). Sriraman (2017) presented CT as “task constraints” that make an idea or product creation. Without task constraints, an idea or product cannot be acknowledged and appreciated using existing knowledge. In general, DT is related to creating variability, and CT is associated with exploring variability. Cropley (2006) argued that there are risks we need to think about when DT and CT are implemented. Without DT, we cannot produce changes, and as a result, we have the risk of stagnation. With DT, there are three possibilities: no CT, CT with rejection, and CT and acceptance. DT without CT is related to the risk of “recklessness,” which can result in disastrous change. It is rare, but when DT without CT turns out to be effective, we can call it luck.

Creative thinking and problem solving can be built into the instruction in many ways, and creative abilities have seen vital to the future success of students (Gregory, Hardiman, Yarmolinskaya, Rinne, & Limb, 2013). Training the creative thinking can be beneficial to students and help them cope with the new situation and find new ways to solve the problem, in other words, the creative thinking give students life skills (Newton, 2013). For that reason, the teacher must be explicitly taught and cultivate creativity in learning mathematics (Švecová et al., 2014).

METHOD

The study was implemented to see the proses student's creative thinking in solving mathematical problems, through a process of workmanship problem solving and interviews with 38 Junior High School students in class VIII's flagship. The goal is to illustrate how the creativity of students in working on the problem-solving.

Participant

Subjects in this study were 38 Junior High School students with math skills vary, 12 students with high math ability, 18 students with the capabilities of the mathematics medium, and 8 students with mathematical ability is low. The entire students are asked to work on the problem-solving tests individually, with its main focus are as follows: (1) students were asked to write down what was known to be reserved; (2) write back what is asked the question; (3) write the problem resolution plan; (4) to resolve the issue in accordance with the plans that have been written; (5) try the other possible alternative in solving problems; (6) checking the back problem resolution.

The process of troubleshooting in this paper follow the scheme of the problem-solving Polya (see Figure 1), just the presentation of the given problem is a matter of open-ended to see the creativity of the students (see Figure 2).

Figure 1. Scheme solving Polya

Kerjakan soal-soal berikut.

1. Apakah parabola $y = x^2 - 2x + 5$ memotong sumbu-x. Jelaskan!
2. Tentukan suatu persamaan garis lurus yang memiliki dua titik potong dengan parabola $y = x^2 + 4x - 5$.
3. Tentukan suatu persamaan garis lurus yang hanya memiliki satu titik potong dengan parabola $y = x^2 + 4x - 5$.

Translation

Work on the following questions.

1. Does the parabola $y = x^2 - 2x + 5$ cut the x-axis? Explain!
2. Find a straight line equation that has two intersection points with a parabola $y = x^2 + 4x - 5$
3. Determine a straight line equation that has only one intersection point with a parabola $y = x^2 + 4x - 5$.

Figure 2. Research instrument

Settings

Students are asked to work on problem-solving (Figure 2) to find out the level of convergent and divergent thinking of students. Then they are asked to understand the context of the tasks in General, and to investigate the ability of problem-solving, can be seen from the results of students' work. At the next stage, students are asked to explain the reason for the problem-solving question of workmanship. At all stages, thought convergence is observed from the ability of the students completing math problems, whereas divergent thinking ability of the students observed from looking for other alternatives of solving problems of Mathematics (see Table 1).

Table 1. Problem resolution activities and his relationship with DT and CT at each stage.

Stages	Problem Solving Activities	Divergent Thinking	Convergent Thinking
Stage 1	Understand mathematical problems in General	See new things of the matter	Given the fact that owned
		See known of reserved as new knowledge	Apply existing knowledge
		Change the perspective (way of looking towards the issue)	Applying a logical strategy
Stage 2	Analysis of the problem resolution plan	Dare to take the risk to try new things	Choose the way to produce the correct answer
		See other alternative possibilities	Just focus on one problem resolution plan
Stage 3	Problem Resolution	Generates many solutions	Generate one solution
Stage 4	Reflection	Using a mathematical representation of ideas and unconventional in	Follow the algorithm of problem-solving

In this way, problem-solving is done by students potentially to categorized in DT and CT. DT and CT is the main component in the formation of the student's creativity, we can create a model of the quadrant to evaluate the results of the completion of the problem of students (see Figure 3), it is in line with the opinion of the Zaslavsky (1995) who say that creativity is the integration between DT and CT.

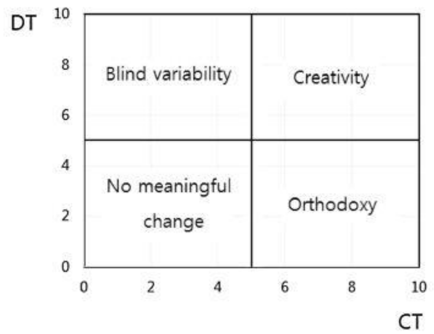

Figure 3. Model 4 quadrants to see problem-solving students

In the blind variability quadrant, element DT high but element CT is low. The problem in this quadrant can ask students to generate some answers, to shift perspective, be unconventional, and to see new possibilities but not particularly paying attention to the underlying mathematical logic and possible connections to previously learned knowledge or relevant information through exploration. This type of novelty which is pursued in this problem is called pseudo-creativity (Cattell and Butcher 1968) or creativity without effort if it is still effective (Cropley, 2006). Instead, on the quadrant orthodoxy, DT elements are low, but the CT element is high. Tasks with high CT and low DT because it usually yields often hold on to accuracy and truth based on previously existing knowledge. The problem of the ideal in a quadrant of creativity is the DT and CT. It's called creativity venture in the sense that knowledge that already exists in the generation of initial capital is the success of the variability (Cropley 2006).

Data Analysis

In addition to seeing the work of students, the data was also obtained from the discussions/interviews with the subject and notes field to know the process of working students in solving problems. The work of the students observed include: (1) the comparative analysis between the work of students with interviews, (2) an analysis of the idea of solving problems of students, and (3) the results of the discussion with the subject. Researchers discuss together students for students working on a matter in which they asked the questions that gave rise to their views and experiences about mathematics. The participants also questioned the idea of another resolution to see divergent thinking of students. Descriptive data to characterize the thinking of students in solving math problems are collected and then used this data to understand more about why they are applying the strategy in a way that they do.

RESULT AND DISCUSSION

The creativity of students in solving the problem of the equation of the line is shown in table 2 below.

Table 2. Problem-solving in each quadrant

Problem-solving in each quadrant	**Many problems can be solved**
No meaningful change	28 (24.6%)
Blind variability	21 (18.4%)
Orthodoxy	42 (36.8%)
Creativity	23 (20.2%)
Total	114 (100%)

Of the 114 Answers students, 36.8% answer students are on a quadrant orthodoxy, which means that students use Convergent Thinking in solving problems and little use of Divergent Thinking. Meanwhile, 18.4% of the answers of the students are on a blind variability, meaning little students using Divergent Thinking, but do not use Convergent Thinking if compared on the other quadrants. From table 2 above can also be obtained information that answers most of the students are on a quadrant of orthodoxy, this is because the questions used in this research is all about problem-solving so many more students using Convergent Thinking off on Divergent Thinking.

No Meaningful Change

Problem-solving in this quadrant is identified in 24.6%. Solving problems of students in this quadrant only up to write down what is known of the matter only, without writing down the problem resolution plan. Students feel difficulties due to content not previously given an exercise similar to the matter of the instrument. Students cannot continue to solving questions administered by researchers.

Students explain the reason why they don't do the changes mean in some tasks. For example, students explain the reason why he just wrote down what is known only:

> May I've been trying to resolve this issue. First, I write down what used to be known, then what was asked. But the initial idea to solve this problem I don't have. Because at the same material

> before my teacher never gives an example of such a problem. From some of the books I read are also no problem like this. But I understand this question is indeed to train my creativity in solving problems, that's why I have difficulty in completing it.

Although fully discuss the role and needs of the DT and CT, a number of students in this quadrant are already feeling that the problem is training the creativity of students in solving math problems. They are concerned with the gap between concept and description of concepts, students show interest in improving CT than DT or without. Students often add some information or opportunities to help to understand to solve the problem.

Blind variability

Many of the answers in this category are identified as much as 18.4%. Student answers in this category showed an increase of encouragement that will produce variability in representations, ideas, and solutions. In the sense that this variability is not explored in relation to the previously existing knowledge, tasks are characterized as the variability of the blind. Students tend to solve the problem with no initial knowledge base, with only a try by not giving clear and definite reasons. If students are aware of the dangers of the blind in resolving the problem of variability and were able to resolve it by involving the initial knowledge societies, then the resulting variability is no problem. If not, then it will only produce solutions which are not meaningful. Expression of students in this category is described in discussions here.

> I am working on this problem with the line through parabolic dabble, then searched the intersection. I am hard-pressed to find the equation of a wide strip because the intersection result pictures do not clear its coordinate. So I decided there was a line that cuts a parabola, but I can't find its line equation.

The given issues encourage students to select and draw a variety of images involving Divergent Thinking. However, students cannot find the intersection point coordinate or cut from a straight line and a parabola that intersect. Although students can draw using linear and quadratic equation, there is a risk that students may not understand the point of the piece and determine its line equation. Students can find pictures using a visual representation provided by the calculator to graph or graph software without understanding or exploration equation. But due to the lack of knowledge that is required to connect the pictures and equations can be meaningless in mathematics.

Orthodoxy

Many answers to students in this category are 36.8%, the largest among the three other quadrants. This is caused due to the fact that students are not getting the education of creativity at school before, as shown in the following discussion:

> What I learned in school is a skill to solve problems. I was interested in was how to get answers to known issues. I am not interested to learn why and how to be creative with my thoughts. So I feel that creativity in solving problems is a very difficult job done.

As mentioned above, the lack of learning experiences in the education of creativity inhibits student involvement in creating variability. Various aspects of the CT as a relationship with the previous concept, implementing an efficient strategy, and collect information considered when students complete problems. Aspects of CT must rely on authority, such as the perspective of the teacher or the correct answer. Students have little freedom to choose the system of representation, the ideas of mathematics, and mathematical procedures they use in this case. CT without DT is similar to the task to see Mastery Learning (Zimmerman and Dibenedetto 2008) or tasks that are developed based on the theory of variation (Runesson 2005).

Problems such as these give students new experiences related to CT than DT. Indeed, the majority of students said that the instructions from teachers are important because of the content they're working on is new and unfamiliar to them. Participants in this study considered orthodoxy is very necessary and even essential to help students understand the material.

Creativity

20.2% of answers students were in this category. There are two types of answers students in this quadrant: the first CT first then followed by DT (convergent-divergent model [CDM]; Foster 2015) and otherwise DT first then followed by CT [divergent-convergent model (DCM)]. In the CDM, the original question is the main focus of the students so that students remember what they have learned before. Next, the students attempted to open up the possibility of deleting or adding conditions. Convergent phase beginning was intended to connect the knowledge and interests of students. The students then conduct the divergent phase by expanding the ideas, concepts, representations, and algorithms with the instructions open and challenging. Instead, in a DCM, the original question asked students to create a variety of ideas, concepts, representations, and algorithms. The next phase, the students explore what they produce. The intent of the convergent-divergent phase after the phase is to be more accurate, logical, and conventional. Some students develop their ability to solve problems using these two models.

Discussion

This research involves 38 Junior students with math skills vary, 12 students with high math ability, 18 students with the capabilities of the mathematics medium, and 8 students with mathematical ability is low. The entire students are asked to work on the problem-solving tests individually, with its main focus are as follows: (1) students were asked to write down what was known to be reserved; (2) write back what is asked the question; (3) write the problem resolution plan; (4) to resolve the issue in accordance with the plans that have been written; (5) try the other possible alternative in solving problems; (6) checking the back problem resolution.

Students answer with no meaningful change categories which mean students interpret the issue as an opportunity to build your creativity. In particular, students consider the level of problem-solving requires knowledge and new ideas, but students don't have them, can only write down what is known only. Although students are given assignments that challenge in integrating cognitive DT and CT like other studies suggested (e.g., Hiebert and Wearne 1993; Stein and Lane 1996), students tend to regard the level of problem resolution is not as desired, because the duties of these cognitively challenged.

This shows that the problem given in daily learning should train the CT and DT. Also, the results show that exposure to challenging tasks in cognitive integrates DT and CT are not enough to prepare students for the solving problem that trains student's creativity. In everyday mathematics learning often does not include the opportunity to understand the reactions of students and apply the approach to "the application of the theory of" traditional (Korthagen and Kessels, 1999; van Akker and Nieveen 2017), which means that students involved in the learning method without the implementation of these tasks. This study explores alternative approaches to learning mathematics effectively in changing students' disposition for the education of creativity. Therefore, this indicates that the granting of problems should be reflected and enhanced creativity based on the reaction of students as it has done in other practices in teaching, which is the conclusion that has been widely recognized in the study of design tasks (Watson dan Ohtani 2015).

Students who complete the problems in the category of blind variability tend to have low motivation in the learning of mathematics. As a result, students open a bit, in terms of representation, strategy, and solutions so that students can easily get involved in DT. Because the context of the problem it is very open, variability was created naturally, but there are no plans to explore and resolve the problem. The shift in Metacognition (Brousseau 2006) are expected and should be handled when using tasks in category variability blind due to the nature of openness of the task. In other words, what the student may not be linked to the main activities, but rather something that is not in accordance with the task. For example, students can only draw straight lines that cut a parabolic equation can search without its line. Therefore, it is necessary a sufficient initial ability in resolving the problem given. It is hoped the teacher would later often gives exercises that stimulate the students to solve the problem so that it can be naturally formed CT (Brousseau 2006).

The third group is students who are categorized as orthodoxy. Students in this category are those who can resolve the issue properly. However, he did not have enough capital to develop ideas, so that tends to only one idea alone. Students need to learn or experience how to dig the idea, representation, and procedures when resolving issues. Research on lack of creativity completed by students (Beghetto et al. 2014; Leikin 2009; Sriraman et al. 2011) who can help the teacher to unearth potential DT students. A possible explanation is that because the teachers pay more attention to learning difficulties when designing lesson than when they designed the task they make related to CT. If so, then we can understand why the teachers feel burdened by applying creativity education in the classroom and how to encourage them to change negative attitudes and their approach to the education of creativity in the classroom.

Students who are unable to resolve the problem that is categorized as creativity using two models: the CDM and DCM. They successfully integrate DT and CT in solving problems so that they can have the opportunity to create and explore the variability. CDM begins by completing an understandable question, as suggested by Foster (2015) and move into the expanded investigation with a more open question as discussed in the findings. Instead, DCM begins with completing the open-ended questions, so that they can brainstorm how to phrase or represent what is given, using metaphor and imagination, and moved into a phase of convergence with linking concepts or mathematical logic, conventional representations, and algorithms.

CONCLUSION

This research contributes to the mathematics teacher to improve the education of creativity in mathematics for learning in the classroom. The investigation is currently done using instruments problem solving algebra with an open-ended question types to analyze the ability of CT and DT students (i.e., a model of the four quadrants) that provides the data that is categorized as an indicator of potential Education creativity and function as a meaningful instrument to distinguish tasks in accordance with the rate at which they reflected DT and CT. Specifically, because CT related to obtains the correct answer to a question, seems to be ignored when creativity is considered in mathematics education. However, it turned out to be most effective in creativity education in which CT integrates well, in the beginning, to attract (Foster 2015) or at the end for elaborate. As pointed out by many researchers of creativity, there are contradictions in the school system, curriculum, and teachers ' views on how to foster creativity in the classroom (Beghetto and Sriraman 2017). Future research about the efficacy of the four-quadrant model should include the assessment of follow-up of the implementation of the tasks of maintenance and enhancement of creativity, and the capacity of teacher and student math is creativity. Such a study would be very helpful to make creativity as an important element in learning mathematics.

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