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Research Article

Describe mathematical creative thinking skills and problem-solving strategies by prospective teacher students on non-routine problems

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ABSTRACT

This study aims to investigate and describe how creative thinking skills and problem-solving strategies are used by prospective mathematics teacher students in solving non-routine problems. Non-routine problems given to the subject require the use of mathematical conceptual understanding and procedural knowledge or algorithms used to find solutions to solve them. The results of the analysis of student-teacher solutions show that each student uses at least two problem-solving strategies. The most frequently used strategies are using algebraic manipulation, making logical reasoning with diagrams/models, and trial and error. Students with high categories show proficiency in using appropriate problem-solving strategies and students with lower categories still show an introduction to solving strategies so that they are confused about choosing the right strategy for a particular problem.

Keywords: creative thinking; problem-solving; non-routine problem; mathematics

1. INTRODUCTION

Creative thinking is an important issue that is currently being discussed in many mathematics lessons. In this case, some experts argue that the main thing of mathematics is creative thinking, not just getting the right answer (Dreifus & Eisenberg, 1996). Teaching mathematics without providing creativity is considered to rule out student potential (Mann, 2006). Piaget's cognitive development theory (1927) states that a child's cognitive development will be optimal at the age of 12 years when students enter secondary school. This allows for an increase in the creativity of students' thinking. But in reality, the case in Indonesia, this is not entirely the case. Learning with traditional methods in most high schools can be said to be the cause of the decline in student creativity at this age, this occurs as a result of pressure so that students can immediately adjust to the developments achieved by their peers (Gube & Lajoie, 2020). This is reinforced by the practice of learning in traditional classrooms which emphasizes practice, demonstration and giving closed questions whose answers are predictable so that they do not prepare students for mathematics. Students complete mathematics learning with adequate computational skills, but cannot apply mathematical skills in meaningful ways (Mann, 2006).

Mathematical creativity in problem-solving is the ability to formulate mathematical problem-solving objectives and find relationships between the parts that make up mathematical problems, this is related to the use of logic and corresponding mathematical concepts (Ervynck, 1991). A relationship explains the relationship between mathematical creativity and students' ability to solve routine and non-routine problems even to approach unstructured problems (Chiu, 2009). The most common indications of creative thinking or divergent thinking are that: requires a lot of ideas/ fluency and can generate unusual responses/ originality (Silvia & Beaty, 2012). Studying and teaching mathematics to achieve creative thinking is a very difficult task because the way of teaching and learning is very demanding and requires creativity itself. Teachers must fully know and understand deeply about mathematics, overcome what students do not know, and do other activities that involve intellectual efforts from both parties (Aizikovitsh & Amit, 2011). However, the teacher must not take refuge from these difficulties. Teachers should challenge themselves to carry out learning that leads to efforts to achieve creative thinking in creative ways as well.

Indirectly, creative thinking skills will lead students to the empowerment of higher-order thinking. Creative thinking is needed by students in solving problems, especially non-routine problems. As is well known, non-routine problems and routine problems are known. Mathematical problems as questions that provide challenges where students are not able to see a clear path or procedure for solving to produce answers or in other words cannot be solved by some routine procedures

that are known to students but the question can still be solved (Cooney, et al, 1975; Krulik and Rudnick, 1996; Mayer, 1992, & Becker and Shimada, 1997). The opinion above says that the mention of mathematical problems is identical to non-routine problems. The basic difference between routine problems and non-routine problems lies in how these problems are able to encourage students to use procedures that are unusual or not easy to guess how to solve. If it does not meet these rules, then the problem cannot be called a mathematical/non-routine problem. The main characteristic of non-routine problem solving is the use of unusual solving procedures. however, several experts have classified several alternative problem-solving strategies, including: algebraic manipulation, Making a Systematic List, Guess and Check, Making a Model or Diagram, Looking for Patterns, Working Backwards, Making Tables, Eliminating Possible Situations, Simplifying the Problem , and Logical Reasoning (Saygili, 2017). Seeing the importance of creative thinking and the application of problem-solving strategies when solving non-routine problems, this study aims to find out: 1) how is the description of students' creative thinking performance levels in non-routine problems? 2). What is the distribution of the application of problem-solving strategies used by students in non-routine problems?.

2. RESEARCH METHOD

The goal of this study is to look at prospective mathematics teacher students' non-routine problem-solving abilities and to map out how they distribute their approaches based on how well they solve problems. Because of its nature, the study must be in a descriptive design. The present study was built using the Case Study Design, one of the qualitative research techniques, because descriptive studies can be either quantitative or qualitative. The present study used a qualitative research approach. Because they make it easier to comprehend participants' thoughts and feelings and to draw on their experiences, qualitative research are chosen (Ekiz, 2009). The Case Study Design, which is based on this methodology, makes it easier to investigate one or more scenarios in all of its features by using a small sample size (Cepni, 2012). Because students' conceptual and practical knowledge as well as their problem-solving abilities were thoroughly examined, this method was recommended in this study. Since every student was evaluated independently within the framework of the study, the Integrated Multi-State Design was also utilized, and the outcomes of every student were compared. This study involved 15 student-teacher candidates from semesters 2, 4, and 6 as research subjects. each semester level by 10 randomly selected students. Each subject was asked to work on 10 non-routine problems within 60 minutes. Subjects are freed to use various problem-solving strategies that have been mastered well according to the given problem. Some of the problem-solving strategies used are algebraic manipulation (AM), Making a Systematic List (MSL), Guess and Check (GC), Making a Model or Diagram (MD), Looking for Patterns (LP), Working Backwards (WB), Making Tables (MT), Eliminating Possible Situations (EPS), Simplifying the Problem (SP), and Logical Reasoning (LR). The answers from the subjects were further classified into 3 measured competency units: Conceptual Knowledge (CK), Use of Understanding Procedural (UP), use of skills and problem-solving strategies (S&PSS).

Table 1. Classification of Conceptual Knowledge (CK)

Level of Creative Thinking		
High	**Moderate**	**Low**
The student uses all relevant information to solve the problem. information to solve the problem	The student extracts the “essence” of the problem,but is unable to use this	The student's solution is inconsistent or unrelated to the question.
The student is able to translate the problem into appropriate mathematical language.	The student is only partially able to make connections between/ among the concepts.	The student translates the problem into inappropriate mathematical concepts.
The student's answer is consistent with the question/problem.	The student's solution is not fully related to the question	The student uses incorrect procedures without understanding the concepts related to the task.

Table 2. Classification of Understanding Procedural (UP)

Level of Creative Thinking		
High	**Moderate**	**Low**
The student uses principles efficiently while justifying the solutions.	The student is not precise in using mathematical terms, principles, or procedures.	The student uses unsuitable methods or simple manipulation of data in his/her attempted solution.
The student uses appropriate mathematical terms and strategies.	The student is unable to carry out a procedure completely.	The student fails to eliminate unsuitable methods or solutions
The student solves and verifies the problem.	The process the student uses to verify the solution is incorrect.	The student misuses principles or translates the problem into procedures.

Table 3. Classification of Skills and proble Solving Strategies (S&PSS)

Level of Creative Thinking		
High	**Moderate**	**Low**
The skills and strategies show some evidence of insightful thinking to explore the problem.	The skills and strategies have some focus, but clarity is limited.	The skills and strategies lack a central focus and the details are sketchy or nor present
The skills/strategies are appropriate and demonstrate some insightful thinking.	The student starts the problem appropriately, but changes to an incorrect focus.	Strategies are random. The student does not fully explore the problem and look for concepts, patterns or relationships.
The student gives possible extensions or generalizations to the solution or the problem.	The student recognizes the pattern or relationship, but expands it incorrectly.	The student fails to see alternative solutions that the problem requires.

Each classification is categorized into three levels of creative thinking: high, moderate, and low. The determination of creative categories at each classification level is determined by a panel consisting of researchers and assisted by 2 lecturers. This is intended so that there is no ordinary judgment in determining the category. Thus, the information presented can be trusted. The following scoring criteria were used to evaluate the subjects' creative thinking abilities: 1 point for the low; 3 points for the moderate, and 5 Points for the high. The medium point for the low and moderate portions was 2 points, and the medium point for the moderate and high sections was 4 points.

3. RESULTS AND DISCUSSION

3.1 Performance Students' Creative Thinking

Each subject was asked to solve ten open-ended problems with an allotted time of 60 minutes. To prevent bias, the work of the subjects was evaluated by a panel of three people. The subject's work outcomes were divided into three categories based on CK, UP, and S&PSS. The average value is shown in **Table 4.**

Table 4. Average of Performance Students' Creative Thinking (CT)

Subject Number	Classification CT	Mean score	Average	Level	Subject Number	Classification CT	Mean score	Average	Level
S_1	CK	4.34	4.27	Moderate/High	S_9	CK	2.56	3,26	Moderate
	UP	3.85				UP	4.10		
	S&SPSS	4.62				S&SPSS	3.12		
S_2	CK	3.48	2.59	Low/ Moderate	S_{10}	CK	4.16	4.42	High
	UP	2.72				UP	4.52		
	S&SPSS	1.56				S&SPSS	4.87		
S_3	CK	2.56	2.48	Low/ Moderate	S_{11}	CK	2.76	2.16	Low/ Moderate
	UP	3.19				UP	1.95		
	S&SPSS	1.68				S&SPSS	1.78		
S_4	CK	1.83	1.68	Low	S_{12}	CK	3.78	3.64	Moderate/High
	UP	1.05				UP	3.86		
	S&SPSS	2.15				S&SPSS	3.27		
S_5	CK	3.53	3.39	Moderate	S_{13}	CK	2.89	1.32	Low
	UP	3.89				UP	1.06		
	S&SPSS	2.75				S&SPSS	1.29		
S_6	CK	3.67	3,14	Moderate	S_{14}	CK	1.63	1.77	Low
	UP	2.91				UP	1.72		
	S&SPSS	2.84				S&SPSS	1.95		
S_7	CK	1.14	1,77	Low	S_{15}	CK	1.20	1.69	Low
	UP	2.42				UP	2.01		
	S&SPSS	1.74				S&SPSS	1.87		
S_8	CK	2.54	2.09	Low/ Moderate					
	UP	2.16							
	S&SPSS	1.56							

Table 5. A Number of Subjects at Each Level

Level	Number of Subject
High	1
Moderate/High	2
Moderate	3
Low/ Moderate	4
Low	5

Tables 4 and 5 also show that there is only 1 subject who has a high level (S10). Additionally, it seems that just 40% of the subjects are at a moderate level and above. Further calculations on Table 4 and Table 5 show that the average creative thinking ability based on the three classifications of CK, UP, and S&PSS is 2.64. This shows that the subject is at the Low/moderate level (between the low and moderate levels). This is not a promising outcome since, as a future mathematics teacher, I believe that all students should learn how to think creatively, especially when it comes to addressing non-routine issues. If the instructor is unable to master the approaches to problem-solving that foster creative thinking, this objective will not be achieved.

Table 6. The average for each classification of creative thinking

Clasification	Mean Score
Conceptual Knowledge	2.80
Understanding Procedure	2,76
Skill & Problem Solving Strategies	2.47

Table 7. The average for each classification of each level student

	CK	UP	S&PSS
High	4,16	4,52	4,87
moderate/high	4,06	3,86	3,95
Moderate	3,25	3,63	2,90
Low/ Moderate	2,84	2,51	1,65
Low	1,74	1,65	1,80

Table 6 and Table 7 provide information that the average Conceptual Knowledge of the subjects is better than the average of Understanding Procedures and Skills & Problem-Solving Strategies. It seems that the subjects have understood the basic concepts of the given problem, but the subjects are often confused or do not know what strategy is appropriate to use in solving the problem. This has an impact on the low understanding of procedures for solving these problems. This information provides a clear picture that understanding the concept alone is not enough to solve an open, non-routine problem. The creativity of students' thinking is tested to find the right strategy to solve it because basically questions of this type can never be solved with procedures/algorithms/procedures that have been commonly used. Students' foresight in finding the right strategy and sacrificing a little time to try various/multiple solving strategies is needed. this is what finally can give the conclusion that the habituation of students dealing with non-routine problems is the main key to generating creative thinking. Various problem-solving strategies are not only known in theory but can be applied to appropriate problems. Students' foresight in choosing and sorting out appropriate problem-solving strategies will provide greater opportunities for students to solve the problems given. This can be seen in students with moderate and above abilities. They can save more time on completion because they know what strategy to use for a particular problem. when the implemented strategy fails, they can immediately switch to using other alternative strategies. This is what distinguishes students with moderate to high levels and vice versa.

3.1.1 Performances Students' Problem-Solving Strategies

The selection of problem-solving strategies is very crucial in solving non-routine problems. This happens because the right strategy will provide convenience in solving the given problem. It is undeniable that a problem can be solved with various strategies at once, but what distinguishes it is the duration of completion and the level of ease. There are questions that are easy to solve using strategy "x", but are actually faster when using strategy "y". There are questions that can be solved with strategy "x" but it's easier if you use strategy "y". Students with high Problem-Solving success levels can choose the correct strategy, or may change the strategy when it does not take them to the result (Koedinger and Tabahneck, 1994). This is in line with the findings obtained from this study. Students' skills in using and choosing strategies are the most important thing in solving non-routine problems.

Table 8. Problem-Solving Strategies Used in Each Item Test

Strategies	Number of Item Test				
	Low	Low/ Moderate	Moderate	Moderate/ High	High
Algebraic Manipulation (AM)	24	15	8	4	1
Making a Systematic List (MSL)	8	5	6	2	2
Guess and Check (GC)	13	11	12	2	0
Making a Model or Diagram (MD)	2	0	3	6	1
Looking for Patterns (LP)	1	0	0	2	1
Working Backwards (WB)	0	1	0	0	2
Making Tables (MT)	0	3	0	0	0
Eliminating Possible Situations (EPS)	1	2	0	1	1
Simplifying the Problem (SP)	1	2	0	2	1
Logical Reasoning (LR)	0	1	1	1	1

Table 8 shows that students have demonstrated the use of several problem-solving strategies. However, when viewed from the results of his work, it seems that the various strategies are less effective. This may also be related to the Understanding Procedure where many students are wrong in carrying out the completion procedure so that the wrong answer is obtained. At this point, it means that students' accuracy and metacognitive abilities need to be improved, besides that of course they need to get used to practice questions. The interesting thing from Table 8 is the use of Algebraic Manipulation and Guess and Check strategies by most students with low, low/moderate, and moderate levels. This shows that students are fixated on trying to generalize the problem by assuming a variable on a known subject matter. they try to use algebraic manipulation (basic algebraic operations, as well as methods of elimination or substitution) to solve most problems. This information can be explained because students in problem-solving experiences, both independently and with previous teacher guidance, are always accustomed to using algebraic manipulation. There is a wrong notion that mathematics is always synonymous with finding the value of "x" or "y" which encourages them to do so. this can be exacerbated if the teacher

who taught them previously never provided alternative answers using other strategies, or used a variety of strategies. The worst result is that students assume that mathematics only has one problem-solving strategy that must be used.

The Guess and Check strategy seems to be more because students are confused in finding the right answer so they try various ways to solve it. Guess and Check is mostly done by looking for an approximate answer that is considered correct and then substituted in the question, if it is appropriate, it is considered that the choice is the correct answer. this step is far from using an appropriate solving procedure or relying more on luck alone. As a result, many students who use this strategy hit a dead end.

Tebl 9. Distribution of solving strategies used in Each Item Test

Number of item test	Used Strategies
Number 1	AM/ GC/ MSL/ LR
Number 2	AM/ GC/ EPS
Number 3	AM/ GC/ MD
Number 4	AM/ GC/ WB
Number 5	AM/ GC/MD/ MT
Number 6	AM/ GC/EPS/ LR
Number 7	AM/ GC/ MSL/LR
Number 8	AM/ GC/ SP/ EPS
Number 9	AM/ GC/ LR
Number 10	AM/ GC/LR/ SP

The information in Table 9 confirms that most students try to use algebraic manipulation strategies and make guesses on all the items given. This indicates that students are not accustomed to using alternative choices of different problem-solving strategies. As a result, the creative thinking level of students will also not be maximized. Strengthening students' creative thinking requires habituation and open thinking to use more varied problem-solving strategies. Thus, students will be more creative in dealing with and solving given problems. Habituation of learning activities by exposing students to on-routine problems is important to train students to optimize their creative thinking intelligence. This is in line with the results of research which states that participants may have paid attention to the feedback they received about previous creative thinking tasks while working on their next creative thinking task (Redifer, Bae, & Zao, 2020). When students can apply creative thinking by using one of the appropriate alternative procedures, then they will be able to use it in other contexts. or he will be challenged to use it in other contexts. It is necessary to introduce and familiarize with the use of various problem-solving strategies from an early age. It is appropriate that the application of simulation training and imitation methods for students must start from the first year (Pyrkova & Ryabova, 2016). Third, from an early age, students are introduced to and taught various non-routine problem-solving alternatives, so students will have many solution ideas that can be used in various problem contexts.

CONCLUSION

The results of this qualitative descriptive study confirm several previous studies that the mastery of students' creative thinking skills in solving non-routine problems still needs to be improved. One of the steps that can be used is to familiarize students with non-routine problems. However, this also needs to be followed by learning in which the teacher needs to present problem-solving with various alternative solutions at once. this is intended so that there is an assumption that mathematics is not just a game of algebra (variable "x") alone. but mathematics should be considered as a unified understanding of concepts, understanding procedures, and choosing the right alternative strategies and not mutually exclusive. The recommendation from the results of this study is learning habits that involve optimizing all students' mathematical thinking potential, not only creative thinking but also need to involve reasoning, communication, critical thinking, and others. Teachers need to change students' mindsets that mathematics is not a set of procedures that have no meaning, but mathematics is a concept of a way of thinking where this way of thinking is the essence of mathematics that can be applied in various situations in real life. The results of this study can also be used as the basis for further research on efforts to empower students' mathematical thinking potential through the application and development of innovative learning models.

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AUTHOR'S CONTRIBUTIONS

The authors discussed the results and contributed to from the start to final manuscript.

CONFLICT OF INTEREST

There are no conflicts of interest declared by the authors.

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