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Students' mathematical lateral thinking skills in creative problem-solving

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Abstract
This study aimed to examine students' mathematical lateral thinking skills in creative problem-solving, differences in subjects' answers based on the level of their study period, and factors that affect students' lateral thinking skills. The descriptive method was used in the form of an educational survey. The sampling technique used in this research was stratified random sampling. The research subjects were first, third, and fifth-semester students of Mathematics Education at FKIP Tanjungpura University in 2019. The data collection technique used was the "Paper-and-pencil Assessment," with the written test sheet adopted from the Mathematical Lateral Logic Test by Bruce Woodcock. The results showed that students' lateral mathematical thinking skills in creative problem-solving were in the poor category, with an average score of 9.39 out of 25. The results of statistical tests with a value of $\chi 2$ indicated that the answers to the subjects were different based on the level of study. The ability to recognize dominant ideas and the polarization of perception of the problem, and the ability to use other ideas are the dominant factors affecting the level of students' mathematical lateral thinking skills in all subject groups. In general, the way of thinking with formal logic or thinking vertically affected students' lateral thinking patterns.

INTRODUCTION

Education has an important role (Intania & Sutama, 2020; Marbun et al., 2020; Maskur et al., 2020; T. Heru Nurgiansah, 2021) in improving the quality of human resources (Kartini et al., 2019; Werdhiastutie et al., 2020). However, Education in Indonesia has become one of the important issues, and significant improvement in the curriculum has happened during the last couple of years (Sunawan & Rosjanuardi, 2019). Based on curriculum studies, it is generally known that mathematics learning is expected to be the development of quantitative reasoning and problem-solving skills, so modeling competencies that are useful for real-world situations (Tong et al., 2019). The learning of mathematics that is developed needs to be linked to the real life of students so that students can be expected to enjoy and tend to like mathematics (Mulbar & Zaki, 2018; Sa'id et al., 2021).

Problem-solving ability is also one of the main goals of learning mathematics (Dewi et al., 2021; Zamnah et al., 2021), meaning that every student activity can be observed through problem-solving activities. Defining a problem, determining the cause of the problem, identifying, prioritizing, and selecting alternatives for a solution, and implementing a solution are known as problem-solving (Hobri et al., 2021; Polat, 2020). Problem-solving is finding

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information to address an issue that emerges in everyday situations. In solving a mathematical problem, prior mathematical knowledge is also needed to help and facilitate students (Widyastuti, 2021). If someone has found a combination of a set of rules or principles that can be applied following the problems at hand, then the person concerned is not only able to solve the problem but also has succeeded in finding new things, namely a set of procedures or strategies that allow someone to increase independence in thinking Gagne in (Wena, 2014).

Creative problem-solving (CPS) in real-world contexts often reorganizes existing knowledge to serve new, problem-relevant functions (Yang et al., 2022). Creative problem-solving is not only an ability about mathematical principles that have been mastered in previous learning but also a process of finding a set of principles or rules in higher-level learning. CPS is a connection between the problem-solving process and creative thinking skills. CPS is a process to provide the framework or system to design or develop a new and useful result (Hobri et al., 2020). Previous studies found that malleable creative mindsets were positively related to insight problem-solving, while fixed mindsets were negatively related to insight problem-solving (Karwowski, 2014). Creative self-efficacy mediates the relationship between creative mindsets, creative problem-solving quality, and originality (Royston & Reiter-Palmon, 2019).

In addition, the purpose of learning mathematics is to train students' thinking skills. Mathematical thinking (MT) has been one of the most important goals for mathematics education as it can support sustainable mathematics learning (Li et al., 2019). Mathematical thinking (MT) is essential for teaching and learning mathematics (Tang et al., 2022) and lies at the heart of mathematics education (Barham, 2020). Teaching and learning mathematics aims to ensure that students can apply and solve related problems (Nasir et al., 2021). It is not only the foundation for children's development (Papadakis et al., 2017) but also the cornerstone of students' sustainable development in mathematics (Dong et al., 2019; Joutsenlahti & Perkkilä, 2019). That goal is related to developing lateral thinking skills and problem-solving abilities to the problems given so that the problems given can be solved as expected. The term lateral thinking was introduced in 1967 by Edward de Bono in his book "New Think: The Use of Lateral Thinking." De Bono states that lateral thinking concerns the generation of new ideas". This statement implies that lateral thinking is related to forming new ideas to solve a problem (Mastur et al., 2021).

According to E De Bono (1994), lateral thinking is the ability to think creatively or "outside the box" by using inspiration and imagination to solve problems by looking at them from unexpected perspectives. Lateral thinking leaves traditional ways of thinking. Furthermore, it is said that lateral thinking is a problem-solving process through a direct and creative approach, using reasoning that is not obvious and involves ideas that may not be obtained by traditional logic. (Edward De Bono, 1994) stated that Lateral thinking is solving problems through an indirect and creative approach, using reasoning that is not immediately obvious and involving ideas that may not be obtainable by using only traditional step-by-step logic.

E De Bono (1994) identified four important factors related to lateral thinking, namely: (1) recognizing dominant ideas and polarizing problem perceptions, (2) looking for different ways of looking at things, (3) relaxation of rigid thinking control, and (4) use the possibilities to encourage other ideas. Lateral thinking ability will sharpen a person's creativity to cope

with anything at hand, as lateral thinking is closely associated with creativity (Susilawati et al., 2019). He maintains that rather than attacking vertical thinking, lateral thinking makes it more effective by adding creativity (Evans et al., 2021). The last factor has to do with the fact that lateral thinking involves ideas of probabilities that may not occur in ordinary events.

Problem-solving poses many difficulties to both students and adults and does not seem to be widely practiced and nurtured in classrooms (Bradshaw & Hazell, 2017). Solving non-routine mathematical problems sometimes need a unique correct answer or solution (Schoenfeld & Sloane, 2016), namely a solution outside the usual procedure. To overcome such problems, students need to be trained in lateral thinking to have skills in solving mathematical problem-solving processes. In this case, high creativity is needed to determine problem-solving procedures beyond expectations.

Mathematical abilities, such as logical thinking and reasoning, problem-solving skills, and mathematical communication that may be obtained at the secondary education level do not guarantee that prospective students are ready to attend lectures at the higher education level, especially in the Mathematics Education study program. When implemented in the first year of Calculus lectures, unable to communicate mathematical ideas verbally (Asih et al., 2019; Pasandaran, 2019) or the use of media is not optimal (Rozie, 2018). In the last two years of Calculus lectures for first- and second-year students of the Mathematics Education Study Program FKIP Tanjungpura University, it is evident that students still face difficulties related to their thinking skills. The ability to think is an important skill that students must develop at university (Abdullah et al., 2020). Generally, students graduate with a C grade in the Calculus course with an average percentage of 40.83% for the Differential Calculus course and 38.68% for the Integral Calculus course, and around 15.56% - 51.28% of students get grades below C. The Calculus course requires critical thinking and creative and problem-solving skills (Moma et al., 2021).

Other researchers have explored problem recognition, idea generation, idea evaluation, and solution validation stages in creative problem-solving (Kumar et al., 2022; Nazzal & Kaufman, 2020). Furthermore, for an understanding of lateral thinking skills and students' creativity in problem-solving, it is necessary to research earlier the provision of lateral thinking skills and students' creativity in problem-solving so that the factors causing their lack of skills in problem-solving activities while attending lectures in the Mathematics Education Study Program can be studied. The purpose of this research, in general, is to examine and analyze more deeply how students' mathematical lateral thinking skills in creative problem-solving. Specifically, this study aims to obtain clarity about (1) the extent to which students' mathematical lateral thinking skills in creative problem-solving; (2) differences in students' mathematical lateral thinking skills in creative problem-solving based on the level of their study period; and (3) factors that influence students' mathematical lateral thinking skills.

METHODS

Based on the problems and data generated in this research, the descriptive research method with educational survey research is a form of research. This study's population was all Mathematics Education FKIP Tanjungpura University students in the 2019/2020 academic year. The sampling technique used in this research was stratified random sampling. Stratified random sampling is a process of dividing the population into strata, choosing a simple random

sampling from each stratum, and incorporating it for use in estimating the population parameters (Ulya et al., 2018). There are 7 (seven) groups taken as data sources, which are as follows:

Table 1. Subjects Used in Research

No	Subject Group	Class Type	Semester	Subject Total
1	A1-1	Regular	1	28
2	A2-1	Regular	1	26
3	B1-1	Non-Regular	1	22
4	B2-1	Non-Regular	1	22
5	A1-3	Regular	3	28
6	B1-3	Non-Regular	3	15
7	A1-5	Regular	5	28
		$\sum$		169

Taking several tiered subject groups was intended to analyze whether students who had attended lectures for a year or more had the same mathematical lateral thinking skills as students who recently enrolled. The object of the research was mathematical lateral thinking skills in solving problem-solving problems.

This research data was collected using the "paper-and-pencil assessment" technique related to problem-solving. With this technique, students were asked to solve a problem of written test about mathematical lateral thinking in solving mathematical problem-solving problems. The data collection tool was a written test sheet with short answers on the instrument sheet given, starting from simple numerical problems and gradually increasing to increasingly complex problems. The adoption of Mathematical Lateral Logic Test was adapted to the conditions in the research subject environment and translated into Indonesian, consisting of 25 items. The test was an essay with short answers with a working time of 100 minutes.

The data collected was analyzed in two ways: quantitative and qualitative. Quantitative analysis to classify student answer data into students' mathematical lateral thinking in creative problem-solving. In addition, quantitative analysis is also to examine whether there are differences in students' mathematical lateral thinking skills in creative problem-solving based on the level of the class of study. At the same time, the qualitative analysis describes the explanation of aspects of mathematical lateral thinking and factors that affect students' mathematical lateral thinking skills.

Regarding quantitative analysis, Bruce Woodcock classifies the level of thinking skills as follows:

Table 2. Level of Thinking Skill by Bruce Woodcock

No	Score	Percentage	Classification
1	17 – 25	$x > 68\%$	Excellent
2	10 – 16	$40\% \leq x \leq 68\%$	Good
3	< 10	$x < 40\%$	Poor

RESULTS AND DISCUSSION

Quantitative Description of Research Results

From the results of the implementation of the Mathematical Lateral Thinking test, the data on the students' mathematical lateral thinking skills scores were presented in the groups of each class as follows.

Table 3. Students' Mathematical Lateral Thinking Skills Scores

No	Subject Group	Classification	Total Students	Percentage
1	A1-1	Excellent	1	3,57%
		Good	17	60.71%
		Poor	10	35,71%
		∑	28	100%
2	A2-1	Excellent	-	-
		Good	8	30,77%
		Poor	18	69,23%
		∑	26	100%
3	B1-1	Excellent	-	-
		Good	14	63.64%
		Poor	8	36,36%
		∑	22	100%
4	B2-1	Excellent	-	-
		Good	21	95,45%
		Poor	1	4,54%
		∑	22	100%
5	A1-3	Excellent	1	3,57%
		Good	9	32,14%
		Poor	18	64,29%
		∑	28	100%
6	B1-3	Excellent	-	-
		Good	1	6,67%
		Poor	14	93,33%
		∑	15	100%
7	A1-5	Excellent	1	3,57%
		Good	18	64,29%
		Poor	9	32,14%
		∑	28	100%

Furthermore, the overall mathematical lateral thinking test results from all subject groups were analyzed by compiling the data recapitulation in the following table.

Table 4. Recapitulation of mathematic Lateral Test results in Creative Troubleshooting

No	Subject Group	Subject Total	Score Total	Score Average	%	Category
1	A1-1	28	300	10,71	42,86	Good
2	A2-1	26	212	8,15	32,62	Poor
3	B1-1	22	226	10,27	41,09	Good
4	B2-1	22	247	11,23	44,91	Good
5	A1-3	28	267	9,54	38,14	Poor
6	B1-3	15	71	4,73	18,93	Poor
7	A1-5	28	311	11,11	44,43	Good
∑		169	1634	65,74	262,98	
Mean		-	9,67	9,39	37,57	Poor

Based on the table data, it is known that overall, students' mathematical lateral thinking skills are still in the Poor category, either calculated from the total score of the whole subject (9.67) or calculated from the total of the seven average scores of each subject group (9.39).

Based on the analysis of the research results, it is known that the overall mathematical lateral thinking skills of semester one students of regular and non-regular classes (APK) are in a good category; the mathematical lateral thinking skills of 3rd-semester students of regular and non-regular classes are in the Poor category; the mathematical lateral thinking skills of 5th-semester regular class students are in a good category. It is indicated that Mathematics

Education students' mathematical lateral thinking skills are still not consistent or fluctuating. In theory, students' mathematical lateral thinking skills should increase in line with their learning experiences and college years.

During mathematics lectures, students face problem-solving activities requiring higher-order thinking skills. So it is hoped that at the lecture level in the final semesters' students' lateral thinking skills should be able to reach the very good category. In fact, out of 169 research subjects, only three (3) people have mathematical lateral thinking skills with an excellent category, one person in each semester.

During the lecture process, of course, students are often faced with solving non-routine problems that require creative problem-solving thinking, both types of problems that require the application of strategy development skills to new problems, and types of problems that require expansion of known skills or theories before applying them to new situations. These two types of problems are considered effective enough to shape the mindset of students in solving various problems while studying in college, as well as problems or problems in real life. However, the study results show that lateral thinking skills are different. In other words, creative thinking that does not always use formal logic (vertical) is considered underdeveloped in Mathematics Education students. This situation becomes material for thought that needs to be considered how to solve it, especially in providing enrichment material for the students concerned.

Furthermore, to examine whether there are differences in students' mathematical lateral thinking skills in creative problem-solving based on the level of the study period (year of college entry), contingency tables and non-parametric χ^2 (chi-square) tests are used. In this analysis, three groups of subjects were taken from equivalent classes, namely A1-1 (1 semester one regular), A1-3 (1 semester regular 3), and A1-5 (1 semester regular 5). The subject's mathematical lateral thinking skills are measured by calculating the value of χ^2. From the calculation of statistical tests obtained, $\chi^2 = 25.9493$. For $\alpha = 0,05$ and db = (3–1)(3–1) = 4 from the Chi-Square Distribution Table obtained $\chi^2_{0,05;4} = 9,48773$. The value of $\chi^2_O = 25,9493$ was greater than $\chi^2_{0,05;4} = 9,48773$ in table χ^2. So it can be concluded that there is a difference in the percentage of subjects' answers on the lateral thinking skills test mathematics in creative problem-solving based on the level of the student study period. This is in line with research conducted by Werdiningsih (2019), which states that lateral thinking has a positive effect and significant result on mathematical problem-solving abilities.

Concerning the Chi-Square statistical test, which results in a χ^2 count value greater than χ^2 tables according to the category of students' mathematical lateral thinking skills, it indicates that the percentage of subjects' answers to the test of mathematical lateral thinking skills in creative problem-solving is quite varied based on the level of the study period, especially on lateral thinking skills. The mathematical category is moderate and low.

Qualitative Description of Research Results

Based on research data, in the subject group A1-1, most lateral thinking skills are influenced by the ability to recognize the dominant idea in the problem (items 10, 11, 13, and 21), the ability to find different ways (17 and 25), and the ability to use possibilities to generate new ideas (14, 19, 22, and 23). Three factors influence this group. In the subject group A2-1, most of their lateral thinking skills are influenced by the ability to recognize the dominant idea in

the problem (points 1, 10, 11, 13, and 21), the ability to find different ways (17, 20, and 25), the ability to think collectively relax (3 and 5), and the ability to use possibilities to generate new ideas (14, 19, 22, and 23). Four factors influence this group.

In the subject group B1-1, most of their lateral thinking skills are influenced by the ability to recognize dominant ideas in the problem (points 1, 9, 10, 11, 13, 16, 21, and 24) and the ability to use possibilities to generate new ideas. (14, 19, 22, and 23). Two factors influence this group. In the subject group B2-1, most of their lateral thinking skills are influenced by recognizing dominant ideas in the problem (points 10, 11, 13, 16, and 21) and using possibilities to generate new ideas (19, 22) and 23. This group experienced few problems answering questions and was only influenced by two factors.

In the subject group A1-3, most of their lateral thinking skills are influenced by the ability to recognize the dominant idea in the problem (points 10, 11, 13, 16, and 21), the ability to find different ways (15, 17, 20, and 25), and the ability to use possibilities to generate new ideas (14, 19, 22, and 23). Both factors influence this group. In the subject group B1-3, most of their lateral thinking skills are influenced by the ability to recognize the dominant idea in the problem (points 1, 9, 10, 11, 12, 13, 16, 18, 21, and 24), the ability to find different ways (7, 17, 20, and 25), the ability to think in a relaxed manner (3, 5, and 6), and the ability to use possibilities to generate new ideas (14, 19, 22, and 23). Four factors influence this group.

In the subject group A1-5, most of their lateral thinking skills are influenced by the ability to recognize the dominant idea in the problem (items 9, 11, 13, 16, and 21), the ability to find different ways (17 and 25), and the ability to use possibilities to generate new ideas (14, 19, 22, and 23). Three factors influence this group. As previously stated, that knowledge results from a learning process that involves thinking activities, with the first character being a mindset called logic and the second characteristic being an analytic thinking process. On the other hand, Wantika (2019) stated that lateral thinking is a process of solving problems through a direct approach and a creative approach, using reasoning that is not immediately clear and involves ideas that traditional logic steps may not obtain. The lecture process that does not develop such logical, analytical, and creative thinking patterns will cause students to be less skilled in mathematical lateral thinking or become inconsistent in their thinking processes which are identified from variations in the percentage of subject answers according to the level of their study period.

Concerning the factors that affect the level of students' mathematical lateral thinking skills, not all groups of the seven groups of research subjects are influenced by the four factors that have been stated, namely (1) the ability to recognize dominant ideas and polarization of perception of problems, (2) the ability to find different ways, (3) the ability to relax rigid thinking control, and (4) the ability to use possibilities to encourage other ideas. These four factors influence two groups of subjects, and the test results show their lateral thinking skills in the poor category.

In addition, two groups of subjects are influenced by three factors (1, 2, and 4), with the test results showing their lateral thinking skills in the good category. There are three groups of subjects who are influenced by both factors (1 and 4), and the test results show their lateral thinking skills in the good (two groups) and low (one group) categories. So it is clear that (E.

Bono, 1994) stated that the lack of ability in these four factors affects a person's level of mathematical lateral thinking.

CONCLUSIONS

The conclusions that can be formulated as a summary of the results of this study are as follows. (1) In general, students' mathematical lateral thinking skills in creative problem-solving at the Mathematics Education Study Program, FKIP Tanjungpura University are in the Poor category with an average score of 9.39 or 37.57% of a score of 25. In particular, students' mathematical lateral thinking skills who have just studied (semester 1) for regular and non-regular classes (PPAPK) in the good category; mathematical lateral thinking skills of regular and non-regular third-semester students in the Poor category; and mathematical lateral thinking skills of 5th-semester regular class students in the good category; (2) The results of statistical tests for the value of χ^2 arithmetic are greater than the value of χ^2 in the table according to the category of students' mathematical lateral thinking skills, indicating that the percentage of subjects' answers to the test of mathematical lateral thinking skills in creative problem-solving varies based on the level of the study period, especially on lateral thinking skills. Mathematics is categorized as moderate and low; (3) Regarding the influencing factors, the ability to recognize the dominant idea in the problem and use possibilities to encourage other ideas are the dominant factors affecting the level of students' mathematical lateral thinking skills in all subject groups. Another quite influential factor is the ability to find different ways. In general, the way of thinking with formal logic or vertically still affects students' lateral mindset in solving creative problems.

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The author's contributions are as follows EY is the coordinator of the distribution of article writing assignments, AYT is the distributor of the sentences in the article, RLP is the data analyzer and DF is the distributor of Mendeley and Grammarly.

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