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ANALYSIS OF STUDENTS' MATHEMATICAL CREATIVE THINKING SKILLS THROUGH PROBLEM-BASED LEARNING ON HIGH SCHOOL

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ABSTRACT

The problem in learning mathematics today is how to develop creative thinking skills and make it a goal in the mathematics learning process, students often assume that mathematics can only be understood by some students. This research aims to descriptively analyze the creative thinking abilities of students whose learning uses the Problem-Based Learning model in Statistics material. This research uses a qualitative and descriptive-analytical approach by examining the data described to get a detailed and in-depth picture of students' mathematical creative thinking abilities in statistics material. The population in this study were all students at SMA Negeri 6 Tasikamalaya with a sample of 38 students in class X-9 at SMA Negeri 6 Tasikmalaya. In this research, it was found that the average student scores on questions number 1, 2, 3, and 4 were 8.81, 8.43, 7.47, and 9.62. From this analysis, students understand better the solution to question number 4 regarding problem number 4. Then the question that has the lowest average value is question number 3 which concerns the study of questions regarding searching for upper quartile and lower quartile data. So, in future research, it is hoped that we will be able to analyze students' abilities in the form of their learning outcomes to see the influence, differences, and interactions that occur in students' mathematics learning outcomes based on their gender.

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INTRODUCTION

The actual issue in mathematics learning today is how to develop creative thinking skills and make it a crucial goal that must be achieved in mathematics learning (Rosidi, 2023). Because mathematical thinking skills are non-algorithmic, complex, involve independence in thinking, it is not uncommon to involve uncertainty so that it requires a lot of consideration and

interpretation (Partono et al., 2021). Mathematical thinking skills also often involve diverse criteria and sometimes trigger conflicts, produce open solutions, and also require serious effort in doing so. Therefore, students' initial mathematical abilities need to be constructed continuously in order to activate higher mathematical abilities (Maryati & Monica, 2021).

Students often assume that in exploring and understanding mathematics can only be understood by a few students (Safithri et al., 2021). Although many learning models can generally make students train their mathematical thinking skills, in learning students are only trained in their activities to listen to learning in mathematical activities carried out by educators (Suryani et al., 2020). Then the mathematical problem solving that is explained is more about one solution that does not cause stimulation to make macro interpretations for students and after that it ends with practice problems which tend to be very differentiated in difficulty. This is called role learning which can be interpreted as learning activities that make students more into memorization techniques without understanding what is being taught, often this is not realized by educators so that it does not seem eccentric if the initial mathematical abilities of students are quite varied and quantitatively very significantly different (Nisa et al., 2023).

Then mathematics learning outcomes are categorized as one of the lowest outcomes in learning (Al Ayyubi, Hayati, et al., 2024; Al Ayyubi, Rohaendi, et al., 2024). The lack of creativity of students in the learning process occurs due to the delivery of educators who are monotonous and without guidance (Rohana, 2022). In addition to low learning outcomes, it can also result in learning becoming less meaningful for students (P. H. M. Astuti et al., 2021). Therefore, learning mathematics requires the right learning model for maximum learning outcomes (Hartati et al., 2020; Widayanti, 2021). In addition, mathematics is still a scourge for most students, resulting in learning outcomes that are below the minimum criteria set by each school (Zaenuri et al., 2020).

Then the learning model is a theoretical framework that can be used as a guide in carrying out the teaching and learning process for students (Anitra, 2021). Meanwhile, learning is an effort to familiarize students to practice and seek knowledge, in which educators and students have an equilibrated role in manifesting the conduciveness and activeness of the learning process (Resmi, 2022). Learning will occur when the learning model used is not only dominated or centered on the educator (Rani et al., 2021). To overcome these problems, there are several learning models that can be used so that students are involved and active in learning mathematics, one of which is Problem Based Learning (Evi & Indarini, 2021; Husnidar & Hayati, 2021; Khikmiyah, 2021; R. Sukmawati, 2021; Widyastuti & Airlanda, 2021).

In addition, research on students' creative thinking skills that are implemented on learning models in Statistics material has not been widely carried out and is still relatively rarely used due to limited adequate facilities and infrastructure (Andriyati, 2023; Kholifah et al., 2018; Mardiani et al., 2023). As well as previous studies that emphasize more on the developmental aspects using STEAM models (Maarang et al., 2023; Putri et al., 2021; Rachmah et al., 2022), Scientific (Astini et al., 2021; Siahaan et al., 2023; Veryawan & Tursina, 2022; Wikaningtyas & Nasir, 2024), Cooperative (Azizah & Diana, 2022; Puspitasari & Nurhandayani, 2023; Y. Yuliati, 2021), ATIK (Aisyah et al., 2023; Udjir & Watini, 2022), Discovery (Erianti, 2022; Heryati, 2021; C. L. Yuliati & Susianna, 2023), Inquiry (Astuti et al., 2023; Rosidah et al., 2022), and game-based models (Budiarti, 2024; Faradisha & Ambara, 2022; Fitriana, 2023). So that the problem-based learning model associated with students' creative thinking skills in statistics material is a novelty in this study.

Thus, to fill the gaps in previous research, this study aims to descriptively analyze the creative thinking skills of students whose learning uses the Problem Based Learning model on Statistics material. As Statistics is closely related to data processing and various formulations that can be

implemented according to the context of differentiated questions and situations. Statistics at the senior high school level is classified into single data orientation and group data. The single data and group data referred to in statistics require creative thinking skills to streamline data processing and calculations. This research is expected to provide new insights as today conventional-based things have been gradually abandoned and are inherently switched with technology in each of these including in the world of education.

METHOD

The method used in this research is a qualitative method with descriptive analysis (Susanty et al., 2023). This research examines qualitative data which is then described to get a detailed and in-depth description of students' mathematical creative thinking skills on statistics material. The population in this study were all students at SMA Negeri 6 Tasikamalaya with a sample of class X-9 at SMA Negeri 6 Tasikmalaya as many as 38 students. The instrument used in this study was a test of students' mathematical creative thinking ability to work on essay questions consisting of 4 items based on the Problem Based Learning model. Data collection techniques conducted by researchers using observation and interviews. Based on qualitative research methods, all written and oral facts from primary and secondary data sources are described as they are and then reviewed to be reduced as concisely as possible to answer the problem. Data collection techniques are efforts to collect materials related to research such as data, facts, symptoms, and information that are valid, reliable, and objective (Creswell, 2010). Data analysis techniques in this study include data collection, data reduction, data presentation, and conclusion drawing (Miles & Huberman, 1992). The flow in the data analysis technique is as follows.

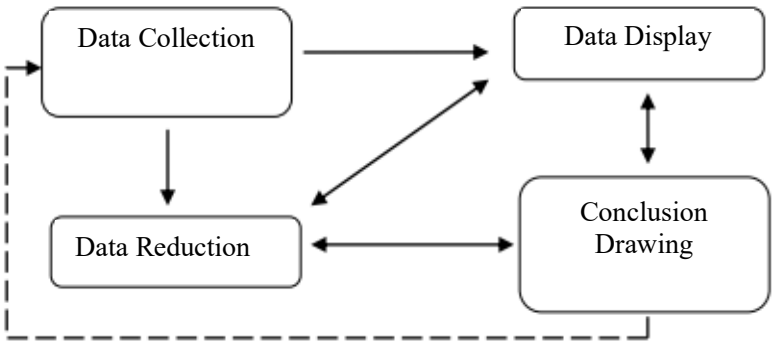

Figure 1. Miles and Huberman's Interactive Data Analysis Model

RESULTS AND DISCUSSION

Results

Based on the statistics problems consisting of 4 items in the statistics material to enhance students' mathematical creative thinking skills through Problem-Based Learning.

Table 1. Average Achievement of Mathematical Creative Thinking Skills

Question Number	Indicator	$\bar{x}$
1	Sensitivity and Fluency	8.81
2	Flexibility	8.43
3	Elaboration	7.47
4	Originality	9.62

Table 1 illustrates that the mean scores for students on questions 1, 2, 3, and 4 are 8.81, 8.43, 7.47, and 9.62, respectively. These questions pertain to group data presented in the frequency table. Question 1 pertains to the mode of the data set, question 2 concerns the median of the frequency table data, question 3 addresses the value of the upper quartile of the development of the median value, and question 4 is concerned with the calculation of the average value of the data contained in the frequency table. The formulas for the mode, median, quartile, and mean values of the data in the frequency table are provided below.

$$\text{Mode} = \text{Tb} + \text{C}\left(\frac{\text{d}_1}{\text{d}_1 + \text{d}_2}\right) \ldots (1)$$

$$\text{Median} = \text{Tb} + \text{C}\left(\frac{\frac{1}{2}\text{n} - \text{f}_{\text{cumulative}}}{\text{f}_{\text{median}}}\right) \ldots (2)$$

$$\text{Lower Quartile} = \text{Q}_1 = \text{Tb} + \text{C}\left(\frac{\frac{1}{4}\text{n} - \text{f}_{\text{cumulative}}}{\text{f}_{\text{Q}_1}}\right) \ldots (3)$$

$$\text{Upper Quartile} = \text{Q}_3 = \text{Tb} + \text{C}\left(\frac{\frac{3}{4}\text{n} - \text{f}_{\text{cumulative}}}{\text{f}_{\text{Q}_3}}\right) \ldots (4)$$

$$\text{Mean} = \bar{\text{x}} = \frac{\sum \text{fx}_\text{i}}{\text{n}} \ldots (5)$$

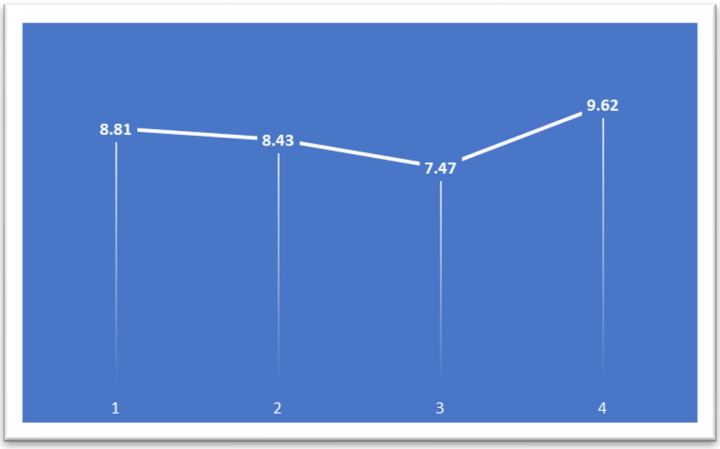

Figure 2. Average Scores of Students in Statistics

In connection with problems number 1 to number 4 which are contained in the formulas in equations (1) to (5) above, students understand more in solving problem number 4 regarding problem number 4. Then for the problem that has the lowest average score is problem number 3 which deals with the study of problems regarding the search for upper quartile and lower quartile data. As for the interview with one of the students regarding the level of ability in solving statistical problems based on students' creative abilities based on Problem Based Learning, "I feel that I don't understand the relationship between the formula of the median and quartiles in finding which class to analyze, so that it can be included in the statistical formula". In addition, students stated that, "To find the average value in the frequency table is very easy to understand, because the analysis needed is only the result of the accumulated multiplication, which is then divided, so that it can be better understood only with regard to speed in solving

the problem". This is in line with previous research that problem-based problems in the average problem in the frequency table data that students more easily understand the solution compared to quartiles, because it is new at the high school level. Meanwhile, the questions to find the mode, median and average values are better understood because at the previous level they have been studied even though they are not in the form of group data or frequency tables.

Discussions

Mathematical Creative Thinking Skills

Based on the description above, the average student scores on questions number 1, 2, 3, and 4 are 8.81, 8.43, 7.47, and 9.62. Question number 1 relates to the mode of data describing students' sensitivity and fluency towards problems with the data mode given, question number 2 relates to students' ability to be flexible in solving problems based on the middle value of data, question number 3 concerns students' elaboration abilities in finding values. From the quartiles of the available group data, question number 4 is related to finding the average value of the data contained in the frequency table with the aspect of student originality. From these results, the students' originality ability in finding the average value of data has the highest score compared to the indicator aspects of other creative thinking abilities, while the lowest value of the students' results is in the elaboration aspect which is related to the value of a quartile. The average value of data can be calculated concretely through addition and division results, while the quartile value is a development of the median value so it can be said to be more partial when compared with other data and requires a deeper understanding to understand quartile value.

In general, it can be understood that the ability to think creatively concerns the ability to produce or develop something new, unusual, or different from the ideas that most people produce. In principle, the various views on the meaning and components of creativity or creative thinking are all in line, but the ways of expressing these opinions often vary. In distinguishing creativity, it is contained in four dimensions expressed as "the Four P's of Creativity", including: 1) person (person); 2) process (process); 3) product (product); and 4) driver (press) (Partono et al., 2021). The explanation of the four "P's" is as follows.

First, the personal dimension (person) implies that a creative person is not only determined by aptitude traits, which include fluency, flexibility, originality, and sensitivity, but also by affective traits (non-aptitude, such as self-confidence, tenacity, and independence). Second, the process dimension refers to the understanding that creative thinking is an ability that reflects fluency, flexibility, originality, elaboration, evaluation, redefinition, and sensitivity in thinking. Third, related to the product dimension, that something is called creative because the product is considered creative in quality, or only in the form of the assessment of people who observe the product and consider it creative. Fourth, related to the driving dimension (press), that creativity depends not only on skills in creative thinking, but also on intrinsic motivation to work hard and interact in a conducive social environment (Setiadi et al., 2023).

In the field of mathematics, the creative thinking ability in question is specifically referred to as mathematical creative thinking ability. With regard to this ability, mathematical creative thinking skills have long included convergent thinking and divergent thinking (Panjaitan & Surya, 2017). These abilities are described into six parts, including the following: (1) The capacity to formulate mathematical hypotheses focused on the cause and effect of a mathematical situation or problem; (2) The capacity to determine patterns that exist in mathematical situations or problems; (3) The capacity to break the deadlock of thought by proposing new solutions to mathematical problems; (4) The capacity to generate unconventional mathematical concepts and to contemplate their implications. The aptitude to discern deficiencies in each problem by posing inquiries to elicit the requisite information. The ability to dissect general problems into more specific sub-problems.

Based on the opinions expressed above, the author argues that mathematical creative thinking in this case is a high-level mathematical thinking ability that includes aspects: (a) sensitivity, (b) fluency, (c) flexibility, (d) elaboration, and (e) originality. The explanation of these aspects of creative thinking is described as follows: (1) Sensitivity, is the ability to catch and find problems in response to a situation, or ignore misleading facts; (2) Fluency, is the ability to build ideas to solve problems in a relevant manner, or provide answers in the form of examples related to certain mathematical concepts; (3) Flexibility, is the ability to use a variety of solution strategies, or the ability to try different approaches in solving problems, or the ability to switch from one approach to another in solving problems; (4) Elaboration, is the ability to explain in detail, coherently, and coherently a certain mathematical procedure, answer, or situation. This explanation uses appropriate representation concepts, terms, or mathematical symbols; and (5) Originality, is the ability to use strategies that are new, unique, or unusual to solve problems, or provide examples that are new, unique, or not the same.

To become someone who is able to think creatively, there are various stages that must be passed, namely there are five stages of creative thinking, which include: (1) Problem orientation, formulating the problem and identifying aspects of the problem; (2) Preparation, where the mind must get as much information as possible that is relevant to the problem; (3) Incubation, when the problem solving process reaches a dead end, let the mind rest for a moment; (4) Illumination, where the thinker begins to get inspiration and a series of insights that are considered to solve the problem; and (5) Verification, the thinker must test and critically assess the solution proposed at the illumination stage (Susanti et al., 2020). In carrying out activities that develop creative thinking skills, it is necessary to pay attention to the components that are involved when someone tries to think creatively. The components are: (1) Creative thinking involves aesthetic and practical standards. This implies that creativity is not only related to good and interesting inventions, but also has a lot to do with inventions that show their applicability or usefulness; (2) Creative thinking depends on the amount of attention to goals and results; (3) Creative thinking depends more on mobility than fluency; (4) Creative thinking is not only objective, but also subjective. One cannot stick to one thing because of rigidity and obsession with objectivity, sometimes it is necessary to be subjective and pay attention to opinions based on feelings; and (5) Creative thinking depends more on intrinsic motivation than extrinsic motivation. This indicates that the drive that arises within a person to think creatively (creative disposition) has a big role in the development of his creative thinking ability (He et al., 2023).

Then the important steps in practicing creative thinking. The four steps include: (1) in thinking do not be easily satisfied and do not accept what is, (2) do not stick to one way, (3) sharpen curiosity, and (4) need brain training. In relation to the challenges that one may face when trying to develop creative thinking skills, one is required to: (1) Work at the edge of one's competence, not in the middle. A person must do work with high competence that makes him challenged to solve a problem even though he does not yet have competence in that field; (2) Review ideas, ideas that are in mind need to be reviewed from different perspectives so that they have the opportunity to bring up other better ideas to be developed; (3) Do something because of internal encouragement and not because of external encouragement. Similarly, if the drive is internal, the person will be proactive. However, if one relies on external encouragement then one will only be a reactive person who will only wait for the urge to create; and (4) A divergent mindset, allowing one thing from different aspects or providing as many answers as possible to one question. The mind must be open, flexible and could see situations from various aspects.

Problem-Based Learning

Problem-based learning is based on constructivism which views that in learning activities, students acquire their knowledge through cognitive conflict as material for induce change. The acquisition of student knowledge begins with the adoption of new things as a result of

interaction with the environment (Andani et al., 2021). Then the new thing is compared with the initial concept (prior knowledge) that has been previously owned. If it turns out that there is no compatibility between new things and students' initial conceptions, then there is a cognitive conflict which results in a disequilibrium in their cognitive structure. Through the accommodation process in learning activities, students can modify their old cognitive structure so that there is assimilation and balance (equilibrium) of the new structure (Sukmawarti et al., 2022).

Problem-based learning is also based on a community-oriented, human-focused educational philosophy, through an interdisciplinary approach and problem-based learning. Learning based on a problem is a constructive cognitive activity, because based on the view of constructive cognitive psychology, learning is a process of constructing new knowledge based on existing knowledge (Husnidar & Hayati, 2021). The description above clearly illustrates that the idea of problem-based learning is developed based on educational theories sourced from Jean Piaget, Lev Semyonovich Vygotsky, and other theories related to social constructivism learning theory and learning design. The constructivism perspective explicitly states that the instructor's role in problem-based learning is as a feedback and reflector of the learning process and group dynamics of the learners.

Here are some views on problem-based learning which is still one of the important innovations in education. Problem-based learning is a learning approach by confronting students with practical problems, usually in the form of ill-structured, or open-ended through stimulus in learning (Arifin, 2021). Meanwhile, problem-based learning is a learning strategy that simultaneously develops problem-solving strategies, knowledge disciplines, and skills to place students in problem-solving activities by making confrontations with problem structures, namely in the form of real-world problems. Problem-based learning can be considered as one of the approaches in learning that challenges students or students as learners to learn and work together in groups in finding adjustments to real problems in their lives.

In this principle of collaboratives, the learning process moves from the transfer of information from the facilitator to the learners to the process of social and individualized knowledge construction. Based on previous opinions, because according to him problem-based learning is based on the assumption that: (1) understanding arises through interaction with the environment; (2) cognitive conflict is a stimulus to understand and determine the organization and nature of what is learned, and cognitive conflict should always be sought to occur in learning; and (3) knowledge develops through social interaction and negotiation. Problem-based learning can be used as an alternative tool to improve thinking ability, develop knowledge and problem-solving skills, learn to share roles through involvement in real experiences, develop effective self-directed learning skills.

The views related to the characteristics of problem-based learning are summarized as follows: (1) Question or problem posing. In problem-based learning activities, teaching is organized around questions or problems that are both socially important, as well as personally meaningful; (2) Focusing on interdisciplinary linkages, meaning that the problem being investigated can be viewed from many points; (3) Authentic investigation. In this case students collect relevant information conduct experiments, seek explanations and solutions with guidance from the lecturer; (4) Produce a product or explanation that represents the form of problem solving found; and (5) There is cooperation required in investigating the problem, identifying sources of information, discussing possible problem solving and presenting the results obtained. Some other characteristics of problem-based learning are as follows: (1) Learner-centered learning; (2) Learning by using authentic problems; (3) Acquisition of new information through hands-on learning; (4) Learning in small groups; and (5) The teacher acts as a facilitator.

Problem-based learning focuses more on students as learning subjects (A. Sukmawati, 2020). Problem-based learning is clearly supported by constructivism theory where learners are encouraged to be able to build and develop their own knowledge. The problem presented is an authentic problem, so that learners are helped more in understanding the problem and can apply it in their professional life later. During problem solving activities, it is possible that there are learners who do not know and understand all the prerequisite knowledge. This situation makes them try to find their own sources. With the formation of groups, it will require a clear division of tasks and clear goal setting as well. Thus, problem-based learning allows scientific interaction and exchange of ideas to build knowledge collaboratively. The role of the teacher in problem-based learning is only as a facilitator. This role provides space for the teacher to lead, guide and facilitate students to be able to achieve the targets that have been set.

From the description of problem-based learning above, it appears that problem-based learning has an important idea that provides a learning environment with problems as its basis. Learning can be achieved if educational activities are centered on authentic, contextual, and relevant tasks or problems, such that learners need to interpret the problem, gather the necessary information, evaluate alternative solutions, and present a confident solution. Thus, learners have the experience that they will face in their professional life. There are several problem-based learning formats that can be implemented in the classroom. Among these formats, the adopted procedure consists of the following steps: (1) The problem is given at the beginning of the lesson before preparation or while learning; (2) The problem situation is presented to the learners in the same way, but should be self-presented in a tangible way; (3) Learners work with problems that are appropriate to their level of knowledge, making it possible for them to reason and apply knowledge to answer challenges and to be assessed; (4) It takes a learning area expressed as a problem, which is explored and used as a guide in individualized study; (5) The skills and knowledge gained in individualized study are applied to the problem to evaluate the effectiveness of learning and to reinforce learning; and (6) The learning gained through working with problems and independent study is summarized and integrated in the knowledge and skills possessed by the learners.

From the whole description of the implementation of problem-based learning, it appears that the existence and role of the teacher as a facilitator is crucial. Although students learn more independently, the teacher has a role that cannot be ignored. The teacher's message as a facilitator should refer to the implementation of approaches that remove barriers to learning and return the learning process to its 'easy' state. In addition, as a tutor, the teacher must work hard to monitor the activities of the learners, activate the learning process and stimulate them with questions, so that the stages of physical and mental activity of the learners can be well known.

CONCLUSION

This study has demonstrated that creative thinking represents an alternative approach to identifying and evaluating novel concepts, which can be evaluated based on Problem Based Learning-derived statistics. The indicators of creative thinking ability include sensitivity, fluency, flexibility, elaboration, and originality. Subsequently, the characteristics of Problem Based Learning include the submission of questions or problems, the organization of teaching around questions or problems that are both socially important, the focus on interdisciplinary linkages, the seeking of explanations and solutions with guidance from lecturers, the production of products or explanations that represent the form of problem solving found, and the cooperation needed in investigating problems, identifying sources of information, discussing possible problem solving, and presenting the results obtained. In the analysis of four items, it can be observed that the average student scores on questions 1, 2, 3, and 4 are 8.81, 8.43, 7.47, and 9.62, respectively. This analysis indicates that students demonstrate a greater understanding of problem number 4 than of problem number 3. The latter is related to the study of questions

about finding upper and lower quartile data. The lowest average value was observed for problem number 3. Further research is recommended to analyze students' abilities in the form of learning outcomes. This will enable the identification of the influence, differences, and interactions that occur in students' mathematics learning outcomes based on their gender.

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