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MATHEMATICAL CREATIVE THINKING REVIEWED FROM LEARNING STYLE AND INDEPENDENCE IN PROBLEM BASED LEARNING

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***Abstract*— All facets of human existence have changed because of the science and technology fields' explosive progress. To the extent that using science and technology can assist other people, technological advancement must be balanced with human nature. The field of education can help shape this way of thinking. One tool for molding human thought processes is mathematics. The purpose of this study is to identify the learning style characteristics of students' mathematics creative thinking abilities. This study employs a qualitative, descriptive methodology. 432 students make up the population and sample of SMAN 4 Cirebon's Class X students using random sampling. This study found (1) the upper class's visual category satisfied the indicators of fluency, flexibility, and detail, while the lower class only met the indicators of authenticity and detail; (2) the upper class's auditory category satisfied the indicators of fluency, authenticity, and detail; (3) the upper class's kinesthetic category fulfilled the indicators of fluency, authenticity, and detail, while the lower class only met the indicators of detail.**

Keywords— ***creative thinking; learning style; independence; problem based learning***

I. INTRODUCTION

Every area of human existence has changed as a result of the scientific and technology fields' explosive progress. To the extent that using science and technology can assist other people, technological advancement must be balanced with human nature. The field of education can help shape this way of thinking. One tool for molding human thought processes is mathematics. Mathematics can help students develop logical, analytical, systematic, critical, creative, inventive, and autonomous thinking skills, according to Rizqi et al. (2021). Rizqi, M., & Nurjali, N. (2023) define creativity as a way of thinking that will result in artistic works or goods as well as the steps required to generate new ideas. According to Ermayani et al. (2023), learning must change students' attitudes and abilities in order to enable them to solve issues creatively. Mathematical creative thinking ability is a crucial component of knowledge since it will assist students in solving difficulties that arise in daily life. Furthermore, according to Nugraha et al. (2023), creative mathematical thinking is an intentional blend of divergent and rational thinking that is grounded in intuition. The capacity to quickly and flexibly solve mathematical issues is known as mathematical creative thinking ability, as explained by Maftukhah, Nurhalim, and Isnarto (2017). As stated by Prayitno & Sridana (2023). Learning style is the result of a person's combination of knowledge management and absorption skills. A person's method of taking in, organizing, and processing information is a mix of their learning style.

According to Saironi & Sukestiyarno (2017), kids' early creative thinking talents are still generally low. Additionally, students preferred procedural questions since they were simple and easy to understand, according to the results of interviews conducted with mathematics teachers at SMP Kesatrian 1 Semarang. Randa (2016) supports this by stating that there is comparatively little mathematical creativity in terms of adaptability, originality, and elaboration. It is also true that students must be pushed to use their creativity when solving mathematical problems in order to develop their capacity to think creatively in the subject of mathematics as stated by Avivah and Faiziyah (2023). Higher level thinking talents can be created through the development of critical, creative, problem-solving, and mathematical reasoning skills. The development of students' creative thinking skills is so crucial. It makes perfect sense for

academics to investigate students' mathematical creativity in thinking.

Numerous studies have looked into the capacity for creative mathematical thought such as the relationship between learning styles and students' capacity for mathematical creative thinking (Istiqomah, Rochmad, & Mulyono, 2017; Triwibowo, Dwidayati, & Sugiman, 2017). Researchers are interested in studying creative thinking abilities in relation to learning styles because, in addition to students' inventiveness in problem-solving, learning styles play a significant role in students' mathematical creative thinking processes and enhance student achievement (Utami, et al., 2023). This interest stems from multiple studies on creative thinking abilities in mathematics. According to Litia (2023), both internal and external influences might have an impact on students' ability to solve issues using creative mathematical thought processes.

According to Afifudin et al. (2017), students essentially learn in accordance with their preferred method, and each method has an impact on the way that ideas are processed and the knowledge that is acquired. Every student approaches problem-solving in a distinctive way, which is assumed to be impacted by their learning style. According to Starko's (2010) research, creative thinking abilities encompass the following components.

1. Fluency is the ability to solve mathematical problems correctly, that is, the answers obtained are relevant to the problem presented and the flow of thought is smooth. Answers are expected to be appropriate, not long-winded so that time efficiency can be obtained in solving problems (Kassim. 2013).
2. Flexibility is the ability to answer problems in mathematics with several appropriate problem and solving strategies. If the methods used are varied but do not refer to the answers requested, then it does not meet the flexibility criteria (Kassim. 2013).
3. Originality is the ability to answer mathematical problems using one's own language, methods or ideas. The answer to a problem is not single, but there are variations of the right answer. The main goal is not to get answers but places more emphasis on the process of how to get to an answer (Marzuki, et al. 2019)
4. Detail (elaboration) is the ability to answer in detail each mathematical problem. Detailed and coherent answers, for example with related concepts.

Problem-based learning is the learning paradigm that is supposed to be able to enhance students' capacity for innovative mathematical thought. According to Wahyuni, Kartono, and Dwjanto (2016), the problem-based learning model is a student-centered, problem-focused, and self-reflective learning approach that involves both teachers and students. According to Astria and Kusuma (2023), problem-based learning is an approach to education that promotes students' comprehension of the subject matter and their ability to apply it to real-world issues. Assisting, providing feedback, guiding, and challenging students to think critically are all ways that teachers can support and encourage students' learning in problem-based learning activities. The role of students in problem-based learning is to be responsible for their learning, building their own knowledge and concepts. Problem-based learning is an appropriate learning model to use to solve problems during mathematics lessons.

Based on this description, the researcher is interested in conducting a study in the form of Mathematical Creative Thinking Reviewed from Learning Style And Independence in Problem Based Learning. In this study, a detailed analysis of how students' learning styles (visual, auditorial, kinesthetics) affect their mathematical creative thinking ability in problem-based learning was conducted. This research offers new insights into more effective adaptation of problem-based learning by considering learning styles, as well as recommending the distribution of learning style questionnaires and routine exercises to improve creative thinking skills.

II. METHOD

This type of research is descriptive research (Al-oweidi, 2013). The results shown from the research are analysed and described whether they meet the indicators of mathematical. creative thinking ability or not. The population in this study were class X students at SMAN 4 Cirebon and the sample was determined randomly. The data collection technique includes two types, namely giving a learning style questionnaire to see the type of learning style each student has. Documentation techniques are used to obtain initial student data which will later be used to determine the research sample (Rizqi, et al, 2021).

Interviews are used to determine students' creative thinking abilities in terms of learning styles and if you want to know the level of creative thinking you can use test questions. In line with Purwono et al. (2015) that students' creative thinking abilities can be done using test instruments and analysis of test results referring to the three components of creative thinking. The three components include fluency, flexibility, and novelty. Supported by Indriani, et al, (2018) the test instrument provided can use essay test questions to measure the level of students' creative thinking abilities.

III. RESULTS AND DISCUSSION

Data on grouping students based on learning styles was obtained from filling out a learning style questionnaire with 30 questions and interviews with several teachers at SMAN 4 Cirebon, the grouping categories, namely visual learning styles, auditory learning styles, kinesthetic learning styles are presented in Table 1 is as follows:

TABLE I. GROUPING OF STUDENTS BASED ON LEARNING STYLE

No	L/P	Posttest Value	Learning Style	Group
1	P	83	Kinesthetic	**Upper Group**
2	L	82	Kinesthetic	
3	P	80	Auditory	
4	L	80	Auditory	

5	P	79	Visual	
6	L	78	Visual	
7	P	75	Visual	
8	P	75	Kinesthetic	
9	L	75	Kinesthetic	**Middle Group**
10	P	74	Auditory	
11	L	74	Auditory	
12	L	66	Visual	
13	P	64	Auditory	
14	P	64	Kinesthetic	
15	L	64	Visual	**Lower Group**
16	P	62	Visual	
17	L	62	Auditory	
18	L	50	Kinesthetic	

Results of Analysis of Mathematical Creative Thinking Ability in terms of visual learning style

The results of the analysis of students' mathematical creative thinking abilities with a visual learning style are in accordance with Stewart, & McDermott (2004). The results of mathematical creative thinking abilities in terms of visual learning styles are presented in Table 2 below.

TABLE II. MASTERY OF CREATIVE THINKING ABILITY INDICATORS FOR VISUAL LEARNING STYLE STUDENTS

No	Sub-ject	Learn-ing Style	Indicators of Mathematical Creative Thinking Ability			
			Smoothness	Flexibility	Authenticity	Details
1	R-32	V			×	
2	R-34		×	×		
3	R-30		×	×		

According to the findings of the analysis of mathematical creative thinking ability in terms of visual learning style, the upper class meets the indicators of fluency, flexibility, and detail in their mathematical creative thinking ability, whereas the lower class only meets the indicators of authenticity and detail. The markers of fluency and flexibility are not satisfied by the lower class, while the indicators of authenticity have not been met by the upper class. Because learning time is divided into groups because of the pandemic, students are not accustomed to working on problems requiring creative mathematical thinking skills, and there are variations in each indicator of mathematical creativity and learning achievement based on learning style.

Meanwhile, based on their findings of research, Rose & Nicholl (2002) state that several factors can encourage creativity in students, one of which is that students with a visual learning style perform better than those with an auditory or kinesthetic learning style. Studies have shown that 70% of the sensory receptors in the human body are found in the eyes. This study is corroborated by Ramlah et al. (2014), whose research findings indicate that learning styles have a major impact on students' achievement in mathematics. However, other study indicates that learning achievement is positively correlated with visual, aural, and kinesthetic learning styles. However, other study indicates that learning achievement is positively correlated with visual, aural, and kinesthetic learning styles. According to Alkathiri et al. (2018), the visual learning style coefficient is 0.080, the auditory learning style is 0.043, and the kinesthetic learning style is 0.079. Al-madani (2015) concurs, arguing that learning styles have a significant impact on learning, particularly on students' capacity for creative thought.

According to Chen et al.'s research findings from 2022, people with varying learning styles exhibit varying levels of creativity in their thought processes, despite having comparable mathematical aptitude. According to Ersoy's (2014) research findings, learning styles have a major impact on students' achievement in mathematics learning.

Results of Analysis of Mathematical Creative Thinking Ability in terms of Auditory learning style

The findings of the examination of students' creative thinking skills in mathematics who have a visual learning style are consistent with Grigg & Lewis (2018). Table 3 below displays the findings of mathematics creative thinking abilities according to auditory learning mode.

TABLE III. MASTERY OF CREATIVE THINKING ABILITY INDICATORS FOR STUDENTS WITH AUDITORY LEARNING STYLE

No	Sub-ject	Learn-ing Style	Indicators of Mathematical Creative Thinking Ability			
			Smoothness	Flexibility	Authenticity	Details
7	R-27	A		×		
8	R-23		×	×		
9	R-21		×	×		×

According to the findings of the analysis of mathematical creative thinking ability in terms of auditory learning style, the upper class meets the indicators of mathematical creativity thinking ability in terms of fluency, authenticity, and detail, while the lower class only meets the indicator of authenticity. Flexibility is one of the signs that has not been met in the upper class, whereas fluency, flexibility, and detail are the indicators that have not been met in the bottom class.

This is because learning time is divided into groups due to the pandemic, students are not accustomed to working on problems requiring creative mathematical thinking skills, and there are variations in each indicator of mathematical creativity and learning achievement based on learning style.

According to Ibrahim (2015), recognizing problems, information gaps, and missing elements, understanding problems, generating conjectures, and formulating hypotheses, testing hypotheses, evaluating, and being able to communicate ideas are all steps in the process of identifying mathematical creative thinking. Meanwhile, if the content is delivered with specific repetitions to help students grasp it better, Shriki (2010) asserts that kids with an auditory learning style would further strengthen their creative thinking talents.

The findings of this study, which are supported by Serva & Wastin (2006), indicate a substantial relationship between learning styles and mathematical achievement. Accordingly,

Irbah and Starko (2010) contend that learning styles have a significant impact on learning, particularly on students' capacity for creative thought. The findings of a 2004 study by Stewart & McDermot, which showed that even though respondents with diverse learning styles had roughly equal arithmetic aptitudes, there were variations in their creative thinking capacities, lend credence to this view. According to Tsai & Shirley's (2013) research findings, learning styles have a major impact on students' achievement in mathematics learning.

Results of Analysis of Mathematical Creative Thinking Ability in terms of Kinesthetic learning style

The results of the analysis of students' mathematical creative thinking abilities with a visual learning style are in accordance with Grigg, & Lewis, (2018). The results of mathematical creative thinking abilities in terms of kinesthetic style are presented in Table 3 below.

TABLE IV. MASTERY OF CREATIVE THINKING ABILITY INDICATORS FOR STUDENTS WITH KINESTETHIC LEARNING STYLE

No	Subject	Learning Style	Indicators of Mathematical Creative Thinking Ability			
			Smoothness	Flexibility	Authenticity	Details
13	R-33	K		×		
14	R-25		×	×		
15	R-28		×	×	×	

According to the findings of the examination of mathematical creative thinking ability in terms of kinaesthetic learning style, the upper class meets the indicators of fluency, originality, and detail for mathematical creative thinking ability, whereas the lower class can only meet the detailed indicators. Flexibility indicators are those that have not been satisfied in the upper class, whereas fluency and flexibility indicators have not been satisfied in the lower class. Because learning time is divided into groups due to the pandemic, students are not accustomed to working on problems requiring creative mathematical thinking skills, and there are variations in each indicator of mathematical creativity and learning achievement based on learning style.

According to the research results, there is a strong connection between learning styles and mathematics learning accomplishment. This research was supported by Chen et al. (2022). Alkathiri et al. (2018) contend that learning styles have a significant impact on learning, particularly on students' capacity for creative thought. The research findings of Tsai & Shirley (2013) provide credence to this opinion, demonstrating that although people with different learning styles may possess comparable mathematical skills, there are variations in their capacity for creative thought. According to Ersoy's (2014) research findings, learning styles have a major impact on students' achievement in mathematics learning.

The findings of Al-madani's (2015) research provide support for the present study, indicating a noteworthy correlation between learning styles and mathematical achievement. Accordingly, Ibrahim (2015) thinks that learning styles have a significant impact on learning, particularly on students' capacity for creative thought. According to Starko's (2010) research findings, individuals with varying learning styles exhibit varying levels of creativity in their thought processes despite having comparable mathematical aptitudes. According to Stewart & McDermott's (2004) research findings, learning styles have a major impact on students' achievement in mathematics learning.

This is consistent with the findings of Rizqi et al. (2021), who claim that the capacity to solve mathematical problems through unconventional means is a sign of flexibility, the capacity to solve mathematical problems through one's own language, ideas, or methods is a sign of authenticity, and the capacity to expand on a problem's solution or generate new ones is a sign of elaboration. Identifying creative mathematical thinking involves a number of activities, according to Rizqi (2021), including identifying problems, information gaps, and missing elements; understanding problems; formulating conjectures and hypotheses; testing hypotheses; and evaluating and communicating ideas. Meanwhile, if the teacher assigns tasks in the form of applied projects or direct practice, students with a kinesthetic learning style can enhance their creative thinking skills even further (Sari, 2014).

IV. CONCLUSIONS

The research findings and discussion data presented in this study suggest that students' mathematical creative thinking abilities in problem-based learning with learning style categorization led to the following conclusions: (1) the upper class's visual category met the indicators of fluency, flexibility, and detail, while the lower class was only able to fulfill the indicators of originality and detail; (2) the upper class's auditorial category met the indicators of fluency; and (3) the upper class's auditorial category met the indicators of fluency, originality, and detail, while the lower class was only able to fulfill the indicators of originality and detail and (3) the kinesthetic category only fulfills the indicators of detail for the lower class, while the upper class is able to fulfill the indicators of fluency, originality, and detail. Therefore, it is advised for future research that students regularly be given practice problems containing indicators of creative thinking; alternative learning models that enhance creative thinking abilities include problem-based learning models that are preceded by the distribution of learning style questionnaires.

There are limitations on this study's findings about kids' capacity for mathematical creativity. First, students struggle because they are not accustomed to solving problems requiring original thought. Furthermore, group instruction was the norm throughout the pandemic, which restricted the ability to optimize teaching strategies. Additionally, there were variations in the markers of mathematics creative thinking capacity based on learning styles, indicating that not all students would benefit equally from the employed strategy.

The inability to adhere to traditional norms or frameworks was also noted as a shortcoming of innovative thinking. Ultimately, an excessive emphasis on creativity could obscure the essence of the lesson or subject matter being taught.

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