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Exploring Students' Mathematical Creative Thinking in the Context of Social Arithmetic

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ABSTRACT

Mathematics education aims to develop students' logical and creative thinking skills, which are essential for solving complex and non-routine problems. Creativity in mathematics is particularly important for problem-solving and critical reasoning. This study analyzes students' mathematical creative thinking abilities in social arithmetic, focusing on fluency, flexibility, originality, and elaboration. This study employed a descriptive qualitative method with a case study approach to explore the complexity of mathematical creative thinking. The research involved 40 second-semester students from the Elementary School Teacher Education program at the Faculty of Teacher Education and Educational Sciences, UNS. Participants were categorized into high, medium, and low academic ability groups. Data collection techniques included a validated test instrument (assessed using the Aiken index), with reliability determined by Cronbach's Alpha coefficient. Interviews were conducted to supplement the test results. Data analysis followed a process of data reduction, presentation, interpretation, and verification. The findings revealed that students' mathematical creative thinking abilities varied by indicator: fluency (57.5%, moderately creative), flexibility (75%, creative), originality (60%, moderately creative), and elaboration (52.5%, moderately creative). The overall average score was 61.25%, categorizing students as creative. The dominant indicator was flexibility, which fell into the creative category. These results suggest that students demonstrate adaptability in problem-solving but may require further development in originality and elaboration. Students' mathematical creative thinking abilities are strongest in flexibility. It is recommended that mathematics educators implement innovative learning models to enhance technological, pedagogical, content knowledge (TPCK) and scientific reasoning.

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1. INTRODUCTION

Mathematical creative thinking is the ability to approach and explore mathematical problems in innovative and original ways. This skill encompasses various aspects, including problem-solving and discovering alternative methods rather than relying solely on conventional approaches. The ability to think creatively is crucial for students, particularly in the context of global competition, where the complexity of modern challenges demands higher-order thinking skills. Creative thinking in mathematics is considered an advanced competency that builds upon fundamental skills in mathematical education (Irdalisa, Hanum et al., 2023; Sugiyanto & Putra, 2021). In this regard, mathematical creative thinking refers to the capacity to generate diverse and novel solutions to open-ended problems by integrating logical reasoning with divergent thinking while maintaining conceptual understanding. According to Widiastuti (2018), this form of thinking involves solving problems and structuring thought processes based on mathematical principles, deductive rules, and conceptual relationships. Consequently, mathematical creative thinking can be understood as the ability to formulate innovative and varied solutions to mathematical problems by synthesizing logical structures and conceptual insights (Fadhillah et al., 2022).

Mathematics is a discipline that is studied at every level of education, from preschool, elementary school, and secondary school to higher education. Beyond the educational sphere, mathematics plays a significant role in everyday life. As a foundational knowledge, mathematics is crucial for the development of science and technology, especially in today's era of globalization, as it aids in shaping human thought processes. Learning mathematics fosters critical, creative, systematic, and logical thinking, which is essential for advancements in science and technology (Ariawan & Putri, 2020). Moreover, mathematics is a fundamental subject throughout all phases of education from elementary school to university (Yolanda, 2021). This indicates that learning mathematics can help equip Indonesia's human resources to think creatively, systematically, logically, critically, and precisely (Zetriuslita et al., 2016). Students must master key concepts and think creatively when solving problems they encounter(Aripin & Purwasih, 2017) . Hence, mathematics education needs to be introduced to students early on.

The goal of mathematics education is to develop students' creative and systematic thinking processes. Mathematical problems serve as contexts that should trigger the process of mathematization and enhance the ability to transfer knowledge to relevant situations. One of the defining characteristics of mathematics is its abstract nature. Solving abstract mathematical problems requires creative thinking during the learning process. Creativity is one of humanity's fundamental needs, representing self-actualization, which is the highest human need. Essentially, every individual is born with different creative potentials (Irdalisa; et al., 2024). Creativity can be enhanced through proper education (T, Laurens, & Moma, 2019) (Irdalisa, Amirullah, et al., 2023). Individuals create primarily because it satisfies them and reflects self-actualization. Eric From defines a creative attitude as the willingness to face challenges, the ability to focus, experiencing oneself as the creator of one's actions, and the willingness to accept debate and tension resulting from the climate of ideas or a lack of tolerance toward creative ideas (Indra et al., 2022). Based on these views, creativity can be understood as the ability to combine previously acquired data or information to produce new solutions.

Some problems related to mathematical creativity abilities in the context of social arithmetic are that many students have difficulty in understanding the basic concepts of social arithmetic, students are often able to understand arithmetic theory but have difficulty when they have to apply it to practical problems, mathematical creativity develops through experimentation and exploration of new ideas. However, many students prefer to follow existing patterns or formulas without trying to find new ways to solve mathematical problems. Besides that, many teachers in both primary and secondary education have yet to observe students' creative thinking abilities fully. In other words, the learning process emphasizes rote memorization over problem-solving, reasoning, critical thinking, or creative thinking. The ability to perform creative thinking is critical in mathematics education to support solving

problems. Observations among students have revealed that the majority still struggle with understanding the material and become confused when faced with non-routine problems that do exist in textbooks. It indicates that students' level of creative mathematical thinking is still low, and their creativity is not well-honed. This condition prompts the researcher to select the Faculty of Teacher Education and Education Sciences as the research location because this institution has the main faction in producing prospective teachers as the main agent of learning process. However, mathematics instruction is often tied to traditional assessments that focus solely on correct answers. This causes students to seek single "best" answers from textbooks without considering alternative methods, thereby stifling creative thinking (Sumartini, 2019).

This issue is supported by data from the 2022 Programme for International Student Assessment (PISA) survey in the field of mathematics, which ranked Indonesia 72nd out of 81 countries, with an average score dropping from 379 to 366. This suggests that the low level of students' thinking processes is one reason Indonesia struggles to compete with other nations. Similarly, Hasanah and Haerudin (2021) cite the Trends in International Mathematics and Science Study (TIMSS) results showing that Indonesian students' creative thinking ability is relatively low. Only 2% of Indonesian students can solve high and advanced-level questions.

In an increasingly modern world, individuals must develop advanced thinking skills, particularly in mathematics. Mathematical creative thinking is the ability to generate new, non-universal ideas while obtaining precise and accurate results. As mathematics plays a fundamental role in various aspects of life, its application extends beyond mathematical disciplines into other fields (Andiyana et al., 2018). This necessity is even more pronounced in the Society 5.0 era, where global competition demands individuals to think innovatively and adapt to complex challenges. To prepare for this, creative thinking skills must be nurtured and developed throughout the learning process (Suripah & Sthephani, 2017).

Mathematical creative thinking consists of four key components: fluency, flexibility, originality, and elaboration (Suripah & Sthephani, 2017). Fluency refers to the ability to generate multiple ideas or solutions when approaching a problem. Flexibility involves solving mathematical problems through various valid methods rather than relying on a single approach. Originality is demonstrated when individuals develop unique and innovative solutions that differ from conventional methods. Lastly, elaboration emphasizes the ability to approach problem-solving through detailed, structured, and systematic steps. These aspects collectively contribute to enhancing students' ability to think creatively in mathematics, equipping them with the necessary skills to adapt and excel in an ever-evolving world.

Based on the above definitions, it can be concluded that creative thinking is one’s capacity to solve a problem by generating multiple ideas or solutions, creating unique ways, or forms that are distinct from others, and expanding the thinking process. As modern life evolves, the ability to think among students progresses, particularly in mathematical thinking. Mathematical creative thinking refers to the ability to generate new and diverse ideas, as well as produce precise and unconventional outcomes. Mathematics has been one of the disciplines that encompass all aspects of life. The goal of mathematical creative thinking is to solve problems by spawning diverse ideas, expanding upon those ideas, and creating novel methods that differ from existing ones (Rasnawati et al., 2019). Several studies on mathematical creative thinking skills have been conducted, such as critical thinking skills in number patterns, plane geometry, or solid geometry (Safaria & Sangila, 2018), and the application of teaching models (Faturohman, Ikhsan, & Afriansyah, 2020). Most of the topics discussed concerning mathematical creative thinking skills are flat geometry and number patterns. It indicates a tendency to connect mathematical creative thinking skills with geometry material. Research by Triyani and Azhar (2021) concluded that students' creative thinking in solving linear equations systems of three variables remains low.

Mathematical creative thinking refers to the general concept of creative thinking (Purwaningrum, 2016). Suripah & Sthephani (2017) point out that mathematical creative thinking aligns with the general concept of creative thinking. Marliani (2015) defines mathematical creative thinking as the ability to

solve mathematical problems using various methods including thinking flexibly, fluently, elaboration, and demonstration of originality. Mathematical creative thinking has been considered as the students' ability to generate diverse and varied solutions to mathematical problems (Muthaharah et al., 2018). Furthermore, Muthaharah et al. (2018) emphasise that creative thinking is essential in mathematics learning, as it facilitates students in solving mathematical problems. Based on these definitions, the researcher defines mathematical creative thinking as the ability to solve mathematical problems using multiple methods, generating a variety of ideas, and creating new approaches. It is not limited to a single method but incorporates alternative approaches that yield the same result.

Handoko and Winarno (2019) argue that when students possess high creative thinking abilities, they can present many alternatives and different solutions to every problem. Moreover, assessing students' creative thinking abilities should not focus solely on the number of answers they can provide but should also reflect the quality and diversity of their responses. Listiani (2020) also explains that creative thinking skills are crucial for students, particularly in the process of learning and teaching mathematics. Through creative thinking skills, students are expected to understand, master, and solve problems by presenting new and creative ideas, and analysing the problems in a precise manner. In light of this situation, the researcher was driven to examine the creative mathematical thinking skills of students at Elementary School Teacher Education (Kebumen), Faculty of Teacher Education and Educational Sciences, UNS. This research entitled Exploring Students' Mathematical Creative Thinking in the Context of Social Arithmetic in Elementary School Teacher Education (Kebumen), Faculty of Teacher Education and Educational Sciences, UNS. The research question posed is how are the students' mathematical creative thinking skills? The purpose of this research is to analyze students' mathematical creative thinking abilities on the topic of social arithmetic. The urgency of this research on the development of creativity in social arithmetic is that social arithmetic often involves real-world situations that require mathematical skills to solve practical problems. By developing creativity, individuals can find new and more effective ways to solve problems related to everyday life, such as budget planning, financial transactions, and data analysis. Research on creativity in social arithmetic can help create more interesting learning methods. A more creative approach can reduce boredom and increase students' motivation to learn.

2. METHODS

This study uses a quantitative descriptive analysis method that involves the use of measurements, numbers, or frequencies to improve the quality of the learning process. The focus of this study is to investigate students' creative mathematical thinking skills. The subjects of this research were 40 undergraduate students in the Social Arithmetic courses from the Elementary School Teacher Education (Kebumen), Faculty of Teacher Education and Educational Sciences, UNS. Some of the reasons researchers chose samples from the Faculty of Teacher Training and Education as the location of the study because this institution is the main forum in producing prospective teachers as the main actors in the learning process besides the lack of students' mathematical creative thinking skills. The reason for choosing social arithmetic is that it covers topics that are very relevant to daily activities, helps in the development of numerical skills, and is directly related to the analysis of social problems. The class was selected for its effective communication skills that support the required data. Data were collected through a written test comprising non-routine questions on social arithmetic and interviews to explore the student's creativity in solving mathematical problems related to social arithmetic.

The instruments used in this research include a social arithmetic test composed of four questions, with each question representing one indicator of creative mathematical thinking, namely fluency, flexibility, originality, and elaboration. Additionally, interviews were conducted to further explore the students' creative thinking skills and to gather supplementary information. The test was administered to 40 students, while unstructured interviews were conducted with nine students based on their performance levels (high, medium, and low). Documentation was also carried out to record the

activities during the research process, supporting the validity of the data related to creative mathematical thinking across the four indicators.

The data analysis technique used in this research followed a quantitative descriptive approach. The data were analysed by describing the students' creative mathematical thinking in solving social arithmetic problems. The students' abilities were divided into three categories: low, medium, and high based on their prior performance as reflected in their previous scores. The data analysis process in this study included several stages: data reduction, source triangulation, analysis of written test and interview results, and concluding.

The student's creative mathematical thinking were analysed for each indicator (fluency, flexibility, originality, and elaboration) using a scoring rubric, a modified version of Bosch's rubric (La Moma, 2015). Each indicator was assigned a score ranging from 0 to 4. Once the total score for each subject was obtained, the next step was to assess the level of creative mathematical thinking. The researcher compared the subject's total score with the maximum possible score for creative thinking. This approach allows for a detailed understanding of the students' creative mathematical thinking skills across the four key indicators and provides a basis for further recommendations to enhance learning processes. Following this analysis, a classification was made based on the modified criteria from Riduwan (2015), as presented in Table 2.

Table 2. Criteria of Mathematical Creative Thinking

Interval	Categories of Mathematical Creative Thinking
81% - 100%	Highly Creative
61% - 80%	Creative
41% - 60%	Moderately Creative
21% - 40%	Less Creative
0% - 20%	Not Creative

3. FINDINGS AND DISCUSSION

The responses provided by students were analyzed to assess their mathematical creative thinking skills in the context of social arithmetic questions. This analysis focused on evaluating fluency, flexibility, originality, and elaboration. The findings, which are detailed in Table 3, offer insights into the extent of students' mathematical creativity as demonstrated in their responses to the presented problems.

Table 3. Description of Students Mathematical Creative Thinking

No	Indicators	Percentage	Criteria
1	Fluency	57,5	Moderately Creative
2	Flexibility	75	Creative
3	Originality	60	Moderately Creative
4	Elaboration	52,5	Moderately Creative
Average		61.25	Creative

Based on Table 3, the average percentage for the fluency indicator was 57.5%. This result indicates that students demonstrated a moderate level of creativity in generating ideas or multiple solutions to problems. This finding is consistent with the view of Febrianti et al. (2016), who suggest that students with fluency skills are those who can pose several questions, effectively communicate ideas, and exhibit quicker thinking compared to their peers.

The flexibility indicator showed the highest percentage, with an average of 75%. This suggests that students were creative in providing diverse solutions from various perspectives. This finding aligns with Fajriah and Asiskawati (2015), who argue that the flexibility indicator in creative thinking is related to the number of ideas generated by students, with answers needing to be varied. The

originality indicator averaged 60%. This reflects that students were moderately creative in producing responses articulated in their words. Samura (2019) mentions that originality refers to the student's ability to solve problems on their own, which is not typically thought of by others.

The elaboration indicator had the lowest percentage of 52.5%. It means that students faced some challenges in elaborating on ideas. This skill can be identified by how students respond to questions in detail and expand upon ideas, as noted by Febrianti et al. (2016). Based on Table 3, the average percentage for mathematical creative thinking skills among students was 61.25%. This suggests that the mathematical creative thinking among students in the Elementary School Teacher Education (Kebumen), Faculty of Teacher Education and Educational Sciences, UNS are considered to be at a creative level. Table 4 presents the triangulated data from tests and interviews.

Table 4. Tringulation Data of Test and Interview

No	Indicators	Test Results	Interview Results
1	Fluency	• Provide answers in a structured, detailed, and accurate manner. • Answer several questions correctly, although with some errors in the responses. • Provide incorrect answers.	-Accurately interprets the problem and comprehends social arithmetic concepts. -Demonstrates limited understanding of social arithmetic concepts. -Exhibits insufficient attention to detail when reading the problem. -Frequently makes errors in identifying social arithmetic concepts within word problems.
2	Flexibility	• Provide correct answers using two different methods. • Utilize two methods but achieve correct results with only one method. • Correctly answers two questions using a single method. • Uses one method to answer, but the answer is incorrect	- Can recognize social arithmetic in story problems -Can find other ways to solve problems -Cannot find other ways to solve problems
3	Originality	• Effectively identifies social arithmetic concepts within word problems. • Demonstrates the ability to find alternative methods for solving problems. • Fails to identify alternative methods for solving problems.	-Has prior experience with similar problems. -Approaches the problem using a trial-and-error method.
4	Elaboration	• Provide answers that are well-structured, detailed, and accurate. • Offer answers that are structured and detailed but contain inaccuracies. • Provide answers that are poorly structured and incorrect. • Fail to complete the assignment.	- Accurately interprets the problem. - Misinterprets the problem. - Lacks sufficient time to complete all questions.

In the fluency indicator, students with high academic ability demonstrated a structured, detailed, and accurate approach to answering questions. However, some still made errors despite their systematic responses. In contrast, students in the moderate and low academic ability groups encountered difficulties in calculations and interpreting questions. Their responses tended to be less structured and detailed, and many struggled to recognize social arithmetic concepts within word

problems. These findings suggest that fluency in mathematical creative thinking is closely tied to students' ability to interpret and process mathematical problems effectively.

Among the four indicators, flexibility had the highest average score. Students with a higher level of thinking flexibility are generally more open to new ideas and adaptable to changing situations. They are better at applying various approaches to problem-solving rather than relying on a single method. In contrast, elaboration—requiring students to expand and refine their ideas—proved to be more challenging. To enhance elaboration skills, teachers can implement strategies such as using open-ended questions to encourage deeper thinking, employing brainstorming techniques to generate multiple solutions, and guiding students to select and develop their best ideas with supporting details, reasons, and examples. Research has shown that students generally prefer using multiple methods to solve problems rather than adhering to a single approach (Suripah & Retnawati, 2019). Within the high academic ability group, most students successfully applied two different methods correctly. The moderate academic ability group primarily relied on one correct method, while in the low academic ability group, only a few students managed to use a single valid method. These results indicate that higher creative thinking skills are associated with the ability to generate new ideas and solve problems from multiple perspectives (Patmawati et al., 2019). Furthermore, interviews revealed that students in the moderate and low academic ability groups faced challenges in identifying social arithmetic problems within word problems. This underscores the importance of fostering students' ability to consider different perspectives and propose diverse solutions to improve creative thinking in the flexibility indicator (Simanjuntak et al., 2021).

Regarding the originality indicator, students in both the high and moderate academic ability groups were generally capable of providing detailed and accurate responses. However, students in the low academic ability group frequently relied on trial-and-error methods rather than structured approaches. This finding highlights a significant difference in creative thinking abilities across different academic proficiency levels (Syahara & Astutik, 2021).

For the elaboration indicator, students in the high academic ability group mostly provided structured and detailed answers with a high degree of accuracy. Those in the moderate academic ability group also demonstrated structured and detailed responses, but some answers were either incomplete or partially incorrect. In contrast, responses from students in the low academic ability group were often unstructured and incorrect, with several students unable to complete their answers due to time constraints. This suggests that while higher academic ability is associated with stronger elaboration skills, there is a need to support students in lower academic ability groups with targeted interventions to improve their ability to develop and expand their mathematical reasoning.

4. CONCLUSION

Based on the data analysis, including the average percentages of mathematical creative thinking indicators, second-semester students in the Elementary School Teacher Education (Kebumen) program demonstrate a relatively high level of creative thinking when solving social arithmetic problems. A significant portion of students successfully identified solutions across all indicators. Specifically, the results show that students' creative thinking skills can be categorized as follows: fluency at 57.5% (moderately creative), flexibility at 75% (creative), originality at 60% (moderately creative), and elaboration at 52.5% (moderately creative). The overall average score of 61.25% indicates that students exhibit a generally creative level of mathematical thinking, though there is room for further development.

These findings highlight the need for educators to enhance instructional methods to further cultivate students' creative thinking skills. Mathematics teachers should incorporate innovative learning models to improve students' Technological Pedagogical Content Knowledge (TPCK) and scientific reasoning. Additionally, implementing strategies that motivate students and foster creativity is essential for strengthening their mathematical problem-solving abilities.

This study recommends that teachers apply various learning models tailored to improve different aspects of student creativity. For instance, project-based learning can enhance originality and elaboration, while collaborative learning methods can refine flexibility and fluency skills. Future research should explore diverse teaching strategies and their impact on creative thinking in various educational contexts, ensuring continuous improvement in students' mathematical creative thinking abilities.

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