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Profile of Pattern Generalization Strategies in Functional Thinking of Middle School Students

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Abstract: This study aims to describe the profile of pattern generalization strategy (SGP) in functional thinking of secondary school students. The profile of SGP in functional thinking of secondary school students in this study is a differentiator in revealing students' pattern generalization strategies in functional thinking in more detail. A qualitative approach was used in this study. Data collection was conducted on 220 students of MTsN 2 Padangsidimpuan. Qualitative analysis from Miles, Huberman & Saldana was conducted to analyze algebra assignments and student interview results. The results showed that students' SGP included arithmetic pattern generalization, factual pattern generalization, contextual pattern generalization, and symbolic pattern generalization. High ability students perform symbolic and contextual pattern generalization activities. Medium ability students generalize factual and contextual patterns, and low ability students generalize factual and arithmetic patterns. The contribution of this research is helping students understand the concept of functional material better, increasing students' generalization abilities, developing students' abstract thinking skills and helping teachers in designing learning methods.

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Introduction

Algebra is one of the important subjects (Agoestanto, et al., 2019; Çetin, 2021; Daud & Ayub, 2019; Kaiser, et al., 2018) that students learn since entering the elementary level. Students' understanding of algebra will play a role in students' lives when they work and pursue higher education (Jupri, et al., 2014; NCTM, 2000). However, some studies state that most students have difficulty in understanding algebra. The difficulties experienced by students include skills (Daud & Ayub, 2019; Wati, et al., 2018; Widyastuti, et al., 2017), concept errors (Aydin-Guc & Aygun, 2021; Natalia, et al., 2016), and students have limitations in understanding algebraic properties (Ndemo & Ndemo, 2018; Tiwari & Fatima, 2019). This shows that there are still many students who do not have the skills and concepts in solving algebraic problems.

The demand in learning algebra is how students' algebraic reasoning in solving problems (Moonpo, et al., 2018). One form of algebraic reasoning is functional thinking which has been introduced since the elementary level (Blanton & Kaput, 2004). This shows that functional thinking is the basis for improving algebraic reasoning skills. Functional thinking is a mental activity in generalizing the relationship between two or more quantities, expressing how the relationship in words, symbols, graphs or tables (Blanton, et al., 2017).

Functional thinking involves generalizing relationships between data that can be honed through solving algebraic problems (Tanişli, 2011). Based on the above, functional thinking is one of the important points in students' algebraic reasoning.

Functional thinking is thinking in generalizing the relationship between two or more quantities (Blanton, et al., 2011). Students who have good functional thinking skills will be able to express the relationship between two quantities using words, symbols, tables or graphs so that these students can reason with various representations to analyze the nature of a function. Smith (2017) defines functional thinking as representational thinking with a focus on a relationship between two or more different quantities. Based on this definition, functional thinking can be interpreted as a style of thinking that focuses on mathematical functions and the student is able to find relationships between functions so that it can help understand and solve mathematical problems. This understanding of functions can help students to identify patterns, trends, and relationships in a broader mathematical context.

Mason, J., Burton, L. and Stace (2010) suggested three stages of thinking in solving mathematical problems namely entry, attack and review. In general, students' functional thinking in mathematics involves functions, relationships, problem solving, generalization and creativity (Frey, Sproesser, and Veldhuis, 2022). Functional thinking can help identify effective solution approaches based on relevant properties of functions. Generalization means that students try to understand concepts more generally and look for common patterns or rules that apply to various situations. It involves the ability to formulate laws or principles that apply to certain functions. Many students struggle to identify and generalize patterns, particularly when it comes to functional thinking, which makes this research crucial. One of the difficulties in learning mathematics at the secondary school level is a poor grasp of the concept of function. Furthermore, our knowledge of how students acquire functional thinking patterns is subpar due to the paucity of research that explicitly addresses pattern generalization strategies (SGP). It is anticipated that this study will shed light on the methods students employ to generalize patterns, which will serve as a foundation for creating more efficient teaching strategies that meet their requirements. The purpose of this study is to describe the profile of pattern generalization in functional thinking of secondary school students. The profile of pattern generalization in functional thinking of secondary school students in this study becomes a differentiator in revealing students' pattern generalization in functional thinking in more detail and specifically.

Research Method

Descriptive research with a qualitative approach was used in this study. This study aims to describe the profile of middle school students' pattern generalization strategy in algebraic problems. A total of 220 VIII students of MTsN 2 Kota Padangsidimpuan were involved in the selection of research subjects. Data collection techniques using total sampling to obtain a broader profile. Researchers used algebra problem tasks using different problems. Researchers modified different tasks in algebra problems for students from the context of problems developed from Utami et al. (2023) and Syawahid (2020).

The data analysis technique according to the analysis stages of Miles, Hubermen & Saldana (2014) begins with data reduction, which is done by identifying pattern generalization strategies in functional thinking through algebra problems completed by students. All data from various sources (tasks and interview results) are filtered and analyzed based on indicators of pattern generalization in students' functional thinking presented in Table 1. Furthermore, relevant data is selected and simplified to focus on important

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information. The next stage is data presentation, where the selected data is arranged in an easy-to-understand form, such as a table or narrative, to describe how the characteristics of pattern generalization strategies in students' functional thinking appear when solving algebra problems. The process is interactive and iterative so that researchers can continue to improve understanding and conclusions.

Results and Discussion

A total of 220 students were involved in the selection of research subjects. The research subjects were taken from three levels, namely HS (high ability subject), MS (medium ability subject), and LS (low ability subject). Based on the results of tests and interviews through functional thinking indicators, student work on algebraic problems is observed in the entry, attack, and review processes in the pattern generalization strategy as shown in Table 1.

Table 1. Indicators of Pattern Generalization in students' functional thinking

Functional Thinking	Indicators of Pattern Generalization
Entry	• Understand the problem deeply and find all the information • Selecting variables to present the problem in the form of symbols, graphs or tables
Attack	• Making pattern conjectures with logical reasoning • Changing a wrong pattern conjecture into a correct one
Review	• Create a general form of the problem • Checking the calculations and functions made

After the test was carried out, the distribution of students based on the level of functional thinking ability was obtained, as shown in Table 2.

Table 2. Distribution of levels of functional thinking

Functional level of thinking	Number of students	Percentage
Low	19	8.64%
Medium	199	90.45%
High	2	0.91%
Total	220	100.00%

Based on the table above, it can be seen that students' functional thinking level is generally at an intermediate level. We need to further analyze this strategy for generalizing patterns from each level. why students in general are more at the intermediate level. To analyze this, it is necessary to take 2 subjects from each level. The selection of these two subjects was carried out so that they could also be used as comparisons and also included checking the validity of the data using source triangulation to obtain the profile of pattern generalization strategies in students' functional thinking.

HS pattern generalization strategy description

There are two subjects taken at a high level, namely HS1 and HS2. HS1 subjects understand the problem in depth and find all the information. HS1 selects variables to present the problem in tabular form. HS1 makes suspected patterns with logical reasons. HS1 converts wrong pattern guesses into correct guesses. HS1 creates a general form of the problem. HS1 checks the calculations and functions created. The results of HS1's work can be seen in Figure 1.

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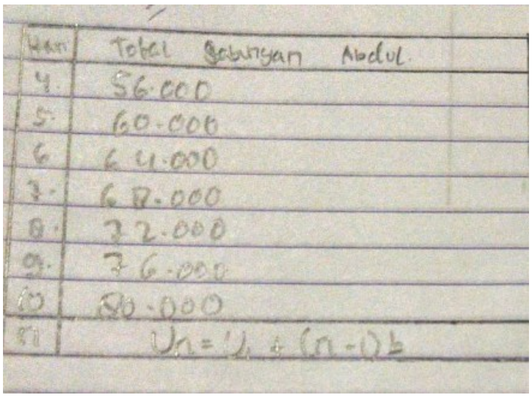

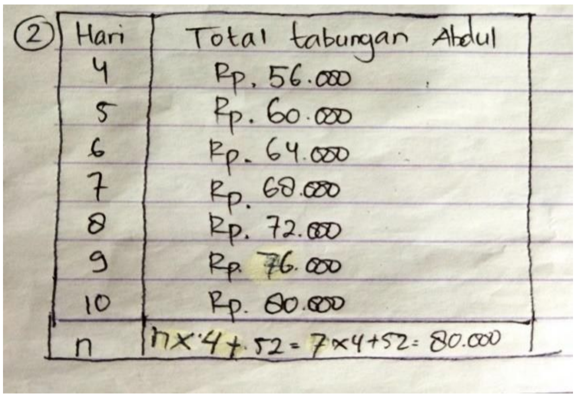

Figure 1. HS1's written answer **Figer 2. HS2's witten answer**

HS1's written answer to the problem as shown in Figure 1 shows that HS can determine the total savings from day four to day seven. HS1 was also able to generalize the desired pattern. In addition, HS1's written answer to the question can be answered well. HS1 is able to generalize the pattern in determining the nth day of savings. HS1 is able to provide the desired answer to the problem. HS1 can correctly predict the pattern based on the information provided by reading the graph in the problem correctly. In addition, HS is also able to generalize the pattern, namely the nth year by forming the symbolic nth term of an arithmetic sequence Un = U1 + (n-1)b. Based on the interview results, it is known that HS1 has been able to get all the information from each problem given, HS1 can also use the right approach in finding the appropriate pattern conjecture. HS1 was also able to generalize the pattern appropriately even though he only used the symbolic method of the row formula to get it. HS2's written answer to the question as in Figure 2 shows that HS2 can determine total savings from day four to day seven. HS2 is also able to obtain the generalization of the desired pattern.

HS characteristics based on the entry, attack, and review stages of students in solving algebraic problems. At the entry stage with the characteristics of students understanding the problem in depth, students find all the information, and students are able to choose variables to present the problem in the form of symbols and tables. At the attack stage with the characteristics of students making pattern conjectures with logical reasoning, and students are able to change the wrong pattern conjecture to be correct. At the review stage with the characteristics of students being able to make general forms (generalizations) of existing problems, and students check the calculations and functions made.

HS is able to generalize patterns through contextualization and symbolization. HS is able to express generalization through symbols of numbers and letters, resulting in generalization of symbolization. According to Mouhayar (2020) this pattern generalization ability is the mastery of contextual generalization and symbolization generalization. The subject expresses generalization through alphanumeric symbols, which bypasses positioning problems to produce nonspatial-based symbolization and goes beyond specific figures and relates to general objects (Mouhayar, 2020). Zazkis & Liljedahl (2002) stated that students' ability to express patterns is not accompanied by and does not depend on algebraic notation and not getting a complete solution is not dependent on algebraic symbols. This means that the student's abilities appear independently depending on the student's initial abilities.

MS pattern generalization strategy description

Subject MS1. MS1's written answer as shown in Figure 3 shows that MS1 was able to make a correct pattern conjecture by adding 4,000 per day until the tenth day. MS1 was

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unable to generalize the pattern to determine the total savings on the nth day even though she already knew the pattern of Abdul's savings increase.

MS1's written answer to the question as shown in Figure 3 shows that MS1 can determine the total savings from day four to day seven. MS1 was able to generalize the pattern in determining savings. MS1 has been able to get all the information from each problem given, MS1 can also use the right approach in finding the appropriate pattern conjecture. MS1 was also able to generalize the pattern correctly even though she only used trial and error to get it.

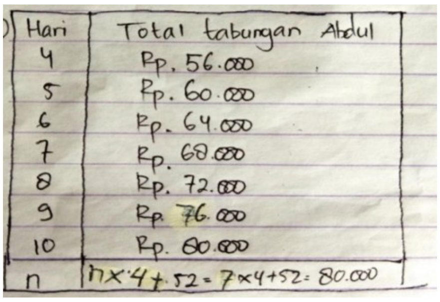

Figure 3. MS1's written answer

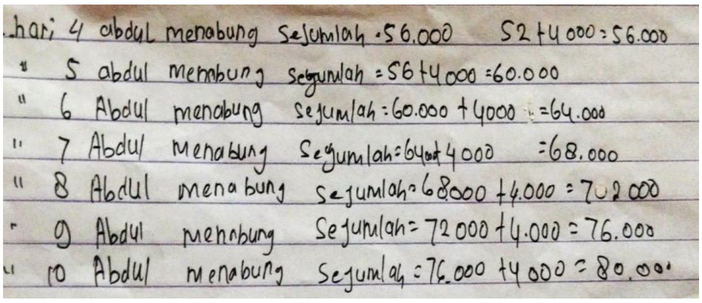

Figure 4. MS2's witten answer

Subject MS2. MS2's written answer as shown in Figure 4 shows that MS2 can predict the correct pattern based on the information from the question. MS4 performs calculations correctly even if there are typographical errors. The writing error made by MS4 was in the answer to determine the total savings on day 5. MS4 wrote 56 +4000 = 60000. MS4 had estimated the pattern correctly but he could not generalize the pattern to determine the total savings on the nth day.

Based on the results of the interview, it is known that MS has been able to answer the question well. MS was able to surmise the pattern based on the information available in the question. However, MS has not been able to generalize the pattern to determine the total savings on the nth day. MS's characteristics are based on the entry, attack, and review stages of students in solving algebraic problems. At the entry stage with the characteristics of students understanding the problem in depth, students find all the information, and students are able to choose variables to present the problem in the form of symbols, graphs or tables. At the attack stage with the characteristics of students making pattern conjectures with logical reasoning, and students are able to change the wrong pattern conjecture to be correct. At the review stage with the characteristics of students not being able to make general forms (generalizations) of existing problems, and students do not check the calculations or functions made.

According to Mouhayar (2020), the ability to generalize this pattern is the mastery of factual generalization and contextual generalization. MS goes beyond the first few steps of the pattern to determine a particular step in the pattern. MS applies to objects at the same concrete level (e.g. numbers) and involves different types of semiotic means of objectification such as linguistic terms spatial positions and gestures in specific steps in the pattern. This is considered a factual generalization (Mouhayar, 2020). According to Lee, (2018), one of the causes of differences in the analysis of students' generalization abilities is due to differences in students' ways of thinking. Many teachers don't know how students think. This certainly affects students' generalization abilities. One of the efforts made by teachers is to provide training on how to find out how students think.

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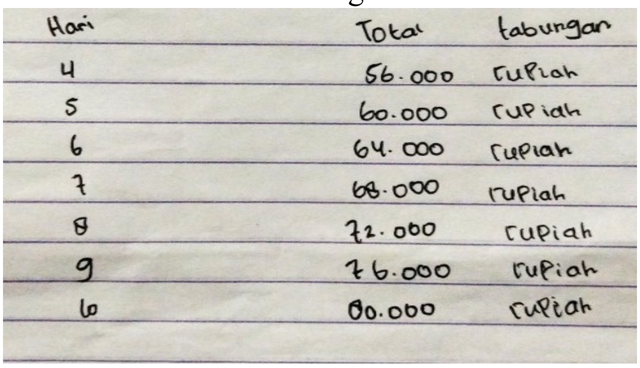
LS pattern generalization strategy description

LS's written answer shows that LS was able to provide the correct answer but LS only wrote the answer without giving the reason for the alleged pattern she obtained. In addition, LS did not write the answer on the nth day which shows that LS was not able to generalize the pattern to determine the total savings on the nth day.

Based on the results of the interview, although LS was able to read the pattern on the graph, LS made a mistake because she thought that the soil erosion area in year 4 and beyond could not be found because the graph only displayed the soil erosion area in years 1 to 3. In addition, LS stated that he did not recheck the answer he gave. Based on LS's written answers and interview data, at the entry stage, LS had fulfilled the characteristics of understanding the problem and had found information. However, LS was unable to select variables to present the problem in the form of symbols, graphs or tables. At the attack stage, LS was able to make pattern conjectures, but did not have reasons and was also unable to change the wrong pattern conjecture. LS did not reach the review stage.



Hari	Total	tabungan
4	56.000	rupiah
5	60.000	rupiah
6	64.000	rupiah
7	68.000	rupiah
8	72.000	rupiah
9	76.000	rupiah
10	80.000	rupiah

Figure 5. LS1's Written Answer

These LS characteristics are based on the entry, attack, and review stages of students in solving algebraic problems. At the entry stage with the characteristics of students understanding the problem, students find all the information, and students are unable to choose variables to present the problem in the form of symbols, graphs or tables. At the attack stage with the characteristics of students making pattern conjectures with no reason and students unable to change the wrong pattern conjecture to be correct. At the review stage with the characteristics of students not being able to make a general form (generalization) of the existing problems and students do not check the calculations or functions made.

Based on LS's work, it shows that LS understands the local similarity observed in some steps of the pattern and is able to extend the similarity to the next terms of the pattern without the ability to generate rules that determine any term of the pattern. According to Mouhayar (2020) LS belongs to arithmetic generalization and factual generalization. Suwanto & Wijaya, (2018) students' algebra and arithmetic generalization abilities cannot be seen only from certain material. Generalization and arithmetic abilities can also be seen from the geometry material (Azis, 2020) and he also stated that looking at students' mathematical generalizations geometrically can be seen from the SAVI approach assisted by Wingeom. According to Hartri & Hakim (2023), LS entered the perception of generality stage because he was able to recognize patterns even though he was not yet able to determine the next number.

Based on the answers and results of interviews with students, HS students' mathematical generalization abilities have fulfilled the functional thinking stages of Entry, Attack and Review. MS has also fulfilled the Entry and Attack stages but at the Review stage,

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MS cannot make generalizations and does not check the results. LS still has problems in all stages of functional thinking. At the Entry stage, LS cannot find the variable. At the Atack stage, LS tries to make generalizations without any logical reason. At the review stage, LS did not meet the indicators at all.

Yildiz & Akyuz, 2020 and Zazkis & LIljedahl (2002) stated that students could not find mathematical patterns due to students' lack of knowledge about algebraic expressions. To overcome this, it is necessary to have teachers who have a good conceptual understanding of mathematics so they can design effective learning. Apart from having good conceptual knowledge of mathematics, teachers also need to understand students' thinking so that teachers can direct students to find mathematical patterns (Yildiz & Akyüz, 2019). Therefore, to hone students' mathematical generalization abilities, the role of the teacher is very necessary.

This study can provide implications for a broad understanding of how pattern generalization strategies work in the context of students' functional thinking. Of course, the results of this study can contribute to the theory of how students can apply the concept of functional thinking so that they can develop students' functional thinking skills in solving mathematical problems. This study can also identify what learning approaches are used in generalizing patterns. Practically, the results of this study can also provide guidance or guidelines for teachers on how to design learning strategies in teaching mathematical concepts related to patterns and functions so that learning becomes more effective. The results of this study also provide knowledge for teachers about how students generalize patterns. This can help teachers provide instructions according to student needs.

Conclusion

Based on the results of the analysis, it is concluded that high ability students perform contextual and symbolic pattern generalization activities. Medium ability students generalize factual and contextual patterns. Low ability students generalize arithmetic and factual patterns. Changes in students' pattern generalization strategies move from arithmetic, factual, contextual to symbolic pattern generalization. Students' mathematical generalization abilities can be supported by the teacher's ability to design learning. Teachers are also expected to be able to understand how students think in order to increase students' mathematical generalization abilities. Therefore, this research has a contribution to mathematics education. With this research, teachers can understand the diversity of students' generalization abilities so that teachers can design learning methods that can improve students' ability to generalize mathematical patterns.

Recommendation

This study focuses on the pattern generalization strategy in students' functional thinking which includes arithmetic pattern generalization, factual pattern generalization, contextual pattern generalization, and symbolic pattern generalization. The results of this study provide recommendations for mathematics teachers and further researchers. For mathematics teachers, it is recommended that learning strategies pay more attention to understanding the concept of patterns and functions, students are expected not to just memorize formulas. Mathematics teachers can use a discussion-based or exploration approach so that they can help students understand how to find patterns and how to generalize patterns. Mathematics teachers are also expected to provide more varied exercises so that students are more accustomed to thinking functionally.

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For further researchers, it is expected to conduct an exploratory study of the factors that influence the low pattern generalization strategy. It can be reviewed from learning styles, cognitive abilities, and previous educational backgrounds. Further researchers can also examine which strategies are more effective in improving students' understanding of patterns and functions. Further researchers can also study how students' decision-making processes in pattern generalization strategies.

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