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Correspondence Relationship Generalization of Junior High School Students in Solving Mathematics Problems

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ABSTRACT

Generalization is a fundamental component of mathematical thinking, allowing students to recognize and articulate patterns beyond specific instances. This study investigates the process and reflection of generalization among junior high school students when solving problems involving correspondence relationships. Generalization is conceptualized as a dynamic process consisting of three core actions: relating, searching, and extending. Reflection of generalization is identified through students' written and oral explanations. Employing a qualitative approach, this research involved 26 eighth-grade students who engaged in problem-solving activities using think-aloud protocols and semi-structured interviews. Based on their approaches to generalization, students were categorized into three groups: (1) global formal correspondence relationship generalization, where students extended patterns using the nth term of an arithmetic sequence; (2) inductive formal generalization, where rules were derived through repeated pattern recognition; and (3) partial formal generalization, where generalizations were made based on selective pattern components. The novelty of this research lies in its detailed analysis of students' cognitive strategies during generalization, a topic that remains underexplored at the middle school level. Given the urgency to enhance mathematical reasoning in early education, these findings offer valuable insights into how students form general rules and relationships, informing instructional practices aimed at nurturing generalization skills. This study contributes to the growing body of research on mathematical cognition by highlighting the diverse ways students engage with and reflect on mathematical patterns.
Keywords: cognitive strategies, generalization, math problems, relationship of correspondence

ABSTRAK

Generalisasi merupakan komponen fundamental dari pemikiran matematika, yang memungkinkan siswa untuk mengenali dan mengartikulasikan pola di luar contoh-contoh spesifik. Penelitian ini menyelidiki proses dan refleksi generalisasi di antara siswa sekolah menengah pertama saat memecahkan masalah yang melibatkan hubungan korespondensi. Generalisasi dikonseptualisasikan sebagai proses dinamis yang terdiri dari tiga tindakan inti: menghubungkan, mencari, dan memperluas. Refleksi generalisasi diidentifikasi melalui penjelasan tertulis dan lisan siswa. Dengan menggunakan pendekatan kualitatif, penelitian ini melibatkan 26 siswa kelas delapan yang terlibat dalam kegiatan pemecahan masalah menggunakan protokol berpikir keras dan wawancara semi-terstruktur. Berdasarkan pendekatan mereka terhadap generalisasi, siswa dikategorikan ke dalam tiga kelompok: (1) generalisasi hubungan korespondensi formal global, di mana siswa memperluas pola menggunakan suku ke-n dari deret aritmatika; (2) generalisasi formal induktif, di mana aturan diturunkan melalui pengenalan pola berulang; dan (3) generalisasi formal parsial, di mana generalisasi dibuat berdasarkan komponen pola selektif. Kebaruan penelitian ini terletak pada analisis terperinci tentang strategi kognitif siswa selama generalisasi, topik yang masih kurang dieksplorasi di tingkat sekolah menengah. Mengingat urgensi untuk meningkatkan penalaran matematika dalam pendidikan anak usia dini, temuan ini menawarkan wawasan berharga tentang bagaimana siswa membentuk aturan dan hubungan umum, yang menginformasikan praktik pengajaran yang bertujuan untuk mengembangkan keterampilan generalisasi. Studi ini berkontribusi pada semakin banyaknya penelitian tentang kognisi matematika dengan menyoroti berbagai cara siswa terlibat dengan dan merenungkan pola matematika.

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Kata kunci: strategi kognitif, generalisasi, masalah matematika, hubungan korespondensi

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Introduction

In mathematics learning, character building can be carried out in students (Bilda, 2016). Curriculum standards and research in mathematics education focus on generalization (Tillema & Gatza, 2017). In generalizing, numeracy skills are needed. Numeracy skills are one of the important skills that students must master as a provision in solving everyday problems (Suciyati et al., 2022). Generalization is one of the important activities in mathematics learning (Hashemi et al., 2013; Mason, 1996; Zazkis et al., 2007; Hill et al., 2015). Generalization is the most authentic exercise in mathematics learning (Strachota, 2016), because generalizations are often described as the core of algebra (Cooper & Warren, 2011; Kieran, 2007). One of the skills that students must master in learning mathematics is generalization (Chua & Hoyles, 2014). The act of generalization is at the heart of mathematical activity, as it serves as a means of constructing new knowledge (Ellis et al., 2017). Material in mathematics learning can be supported by generalization (Setiawan et al., 2020). So generalizations have a strong role in elementary level mathematics (Council, 2001; NCTM, 2006). The role of the teacher is also very necessary because teachers need to familiarize themselves with various ways to introduce generalizations by involving students in an act of generalization (Strachota, 2016). Generalization is part of functional thinking. Functional thinking is part of algebraic thinking (Syawahid & Sucipto, 2023). Functional thinking is related to a relationship between two or more variables and the generalization of a relationship between several quantities, Smith (Suryowati, 2021). This is in line with Markworth (Suryowati, 2021) who stated that functional thinking is a representation of thinking that focuses on the relationship between two or more variations or quantities. The main topic of algebraic thinking is functional thinking and can enrich students' experiences in mathematics (Stephens et al., 2012).

Correspondence relations describe the relationship between two patterns through a rule (formula), describing how to determine y or f(x) if given a value of x. Generalizing correspondence relations is the process of finding a formula or general rule of a two-quantity relationship to a function. Research on the generalization of the correspondence relationship, among others, is Carraher's research and Canadas. Both studies describe how elementary school students generalize the correspondence relations of two quantities (Carraher et al., 2008; Canadas et al., 2016). This research was conducted on junior high school students and the process of generalizing correspondence carried out by students in the study was different from the results of research by Carraher and Canadas. This study will describe how junior high school students conduct the process of generalizing correspondence in solving math problems. Generalization ability in this study is seen from the students' generalization process through the stages of relating, searching and extending in solving mathematics problems.

According to (Dumitrascu, 2017) generalization is the duality between the shift from something special to something general and seeing something special through something general. Mathematical generalization is a statement that some properties or techniques apply to a set of mathematical objects or broader conditions (Carraher et al., 2008). Generalizations can be made to patterns, procedures, structures, and relationships (Kaput, 1999). Generalization in this study is a generalization of the correspondence relationship. Correspondence relation is a type of functional relationship. There are two types of functional relationships, namely correspondence relationships and covariation relationships (Confrey & Smith, 1995). Correspondence relationship describes the relationship between two patterns through a rule (formula), describing how to determine y or f(x) if given an x value (example: y=4x+1). Covariation relationships describe the relationship between two patterns that show how the quantity in a pattern changes when other quantities in a pattern also change (Confrey & Smith, 1995). In this study the generalization of the correspondence relationship will only be described. Students in basic education have reasoned about covariation and correspondence relationships (Blanton & Kaput, 2004; Martinez & Brizuela, 2006; Stephens et al., 2012). So that this research can be done on junior high school students.

Generalization of the correspondence relationship in this study is described using the generalization and reflection of generalization (Ellis, 2007). Generalization actions are divided into three, including relating, searching and extending. Reflection generalization is a statement of student generalization in the form of verbal statements or written statements. Related action consists of connecting situations (connecting with previous or creating new ones) or connecting objects (their nature or shape). The action of searching consists of finding the same relationship or looking for the same procedure or looking for the same pattern or looking for the same results. Extending action consists of extending the range of applications or eliminating specific things or through operations or continuing patterns (Ellis, 2007). Three cognitive factors in pattern generalization, namely competence with number relations, competence with shape similarity, and competence with the construction, acuity, and justification of figurative properties (Rivera, 2018). Research on junior high school students' generalization includes research by Aprilita et al. (2016) which grouped 30 students into 3 categories, namely 16.7% low mathematical generalization ability, 70% medium mathematical generalization ability and 13.3% high mathematical generalization ability. Generalization ability is seen from the aspects of perception of generality, expression of generality and symbolic of generality. This study groups students based on the generalizations made. Generalization in this study through the stages of relating, searching and extending. The research question in this study is how to generalize the correspondence relationship of middle school students in solving math problems?

Research Methods

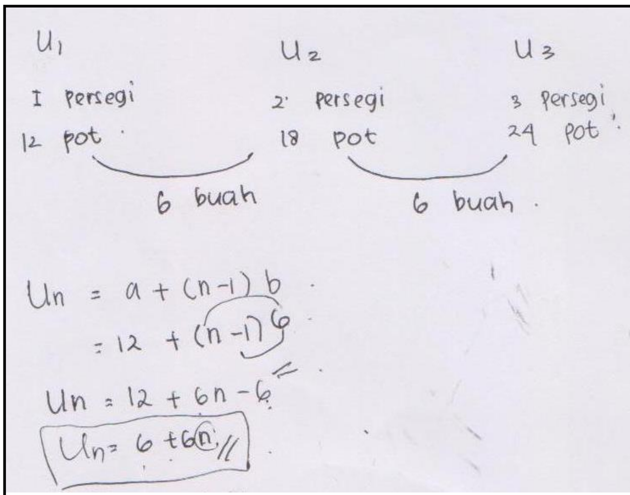
This study uses a qualitative approach. Several characteristics of research with a qualitative approach, namely the research process always develops dynamically (Creswell, 2012). As many as 50 students in eight grade junior high school students who have been selected by math teachers at school based on their mathematical abilities and communication. Students work on mathematics problems by thinking aloud, which is working while voicing what they think. This research was conducted in 2018. The data collection technique is through giving math problems and interviews. to see the generalization process carried out by students. The data obtained will be analyzed inductively, researchers create categories inductively, researchers create a comprehensive picture of the problem being studied (Creswell, 2010).

The selection of this subject is based on the recommendation of the school's math teacher. This study was stopped after 50 students because there were no more general characteristics of the correspondence relationship that emerged. Of the 50 students, 26 students were correct in solving math problems about patterns. Based on the work of students, there were 26 students who worked on the math problem correctly the students were interviewed. Then students are grouped based on the process of generalizing the correspondence relations that are carried out. There are three groups which can be explained that the first 4 students use the nth term formula to determine the general rule. Second, 17 students determine the general rule inductively. Third, 5 students determine the general rule partially. Each group is taken by one student to be the subject of research, so there are 3 subjects that will be described as a generalization process. The first group is called the global formal correspondence relationship generalization, the second group is called the inductive formal correspondence relationship generalization and the third group is called the partial formal correspondence relationship.

Result and Discussions

The Global Formal Correspondence Relationship Generalization

Based on the answer of first subject (Figure 1) and the results of the think-aloud, the corresponding S1 action connects the number of squares and pots by grouping the number of squares and pots on each model, model 1, model 2 and model 3. S1 uses the term u1 for model 1 (1 square with twelve pots), u2 (2 squares with eighteen pots), and u3 (3 squares with twenty four pots). S1 classifies the number of squares and pots on each model and is placed sequentially. Generalization reflection of subject can be seen in written statements and oral statements.



Translate into English:

U_1	U_2	U_3
1 square	2 square	3 square
12 pot	18 pot	24 pot

6 pieces   6 pieces

$$U_n = a + (n-1)b$$
$$= 12 + (n-1)6$$
$$U_n = 12 + 6n - 6$$
$$U_n = 6 + 6n$$

Figure 1. The Answer of First Subject (S1)

Following is the excerpt of the interview:
R : What do you mean by u1? "
S1: "one tribe, so one tribe is the first tribe"
R : "the first tribe ... which one is here?"
S1: "the model 1 will have 1 square with 12 pots"
R : "what do you do?"
S1: "the 2 squares with 18 pots"

S1 performs searching by looking for differences or differences in the number of pots on the known model. In the given question, the subject observes the number of squares and pots of model 1, model 2 and model 3. However, S1 focuses more on the number of pots by calculating the difference or the difference in the number of pots of each model. The following is the excerpt of the interview with S1:

R : "You wrote this number 6, please explain the point?"

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S1: "So here model 1 is described as u1, u1 has 1 square and 12 pots, u2 has 2 squares and 18 pots, u3 has 3 squares and 24 pots, now I'm here to make it easier for me to find the difference because in the formula using difference, there are so many u2 pot to be reduced by a lot of pots in u1 which has 12 pots"

S1 extends by concluding the answer. Because the difference or difference is the same, S1 uses the formula in Un = a + (n-1) b to determine the number of pots in the nth model. S1 concludes that there are 6 + 6n pots that can be placed on the nth model. As shown in the excerpt of the interview with the following S1:

R : "You write Un = a + (n-1) b?"
S1: "yes"
R: "why are you using that method?"
S1: "because the difference from u2 to u1, u3 to u2 can have the same way when using this formula, whereas later if there is another difference found is different then I will use a different formula again."
R: "so on the nth model, how many flower pots can you put?"
S1: "12 + 6n - 6 = 6 + 6n"

In the generalization of this global formal correspondence relationship there is a horizontal mathematical process and vertical mathematical process. According to (Wijaya, 2012) the horizontal mathematical process begins with identifying mathematical concepts based on order and relationships found through visualization and schematic problems. Whereas vertical mathematical process is a form of formalization process where mathematical models obtained in horizontal mathematics become the basis for the development of more formal mathematical concepts. The strategy used by the subject is chunking; taking the common difference between two terms in a sequence, multiplying it by the number of steps, and then adding this product to the initial term in the sequence (El Mouhayar & Jurdak, 2016).

The horizontal mathematical process of generalizing this formal global correspondence relationship can be seen from the search for the regularity of relationships and the transfer of real problems into mathematical models. The subject looks for order and relationship of the model (pattern). The subject looks for regularity in the difference in quantity of a part (element) of the model (pattern) that is known. The subject connects the quantity of a part (element) model (pattern) 1 to model 2 and model 3. Vertical mathematical processes occur when the subject represents a relation into a formula or rule. This is done by the subject when extending, the subject makes the general rule. The subject uses the formula Un = a + (n-1) b to make a general rule, taking into account the regularity of the difference in quantity of a part of the model (pattern).

The Inductive Formal Correspondence Relationship Generalization

Based on the answer of second subject (Figure 2) and results of the aloud, on the action of the subject by grouping the number of pots on each model and placed sequentially. The subject connects the number of empty spaces (square) with the number of pots on the known model. As shown in the following interview passage:

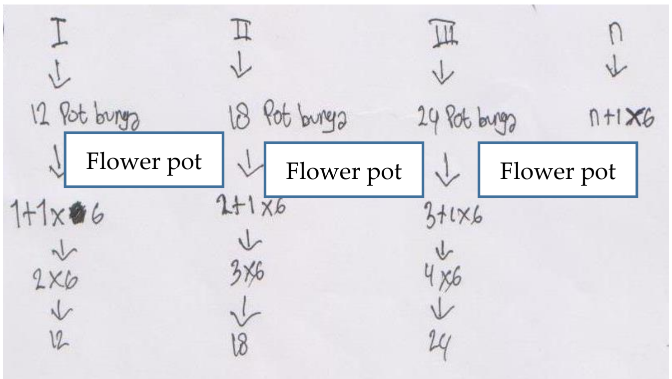

Figure 2. The Answer of Second Subject (S2)

R : "Then the second one you write I, II, III what do you mean with this?"

S2: "I mean this is one empty space where there are twelve flower pots and (while pointing II) ... two empty spaces where there are 18 flower pots, and (while pointing III) ... there are three square or three empty spaces where there are 24 flower pots."

In the act of searching the subject looked for the same method or procedure to calculate the number of pots on each model. As shown in the excerpt of the interview with the following S2:

R : "Then the second one you write I, II, III what do you mean by this?"

S2: "From here I am looking for how one empty space or one square there are 12 flower pots, two empty spaces or two squares can be 18 flower pots, here I have included the method (while pointing to the answer)."

R : "Where did you get this method ... where did the idea come from?"

S2: "First I just guessed it ... just fad ... I tried it in my mind why it didn't fit ... finally I moved again ... I imagine the formula is n2 multiplied by 6, then I imagine in my mind why it doesn't match the results so I try again with a different formula and try again. "

R : "what doesn't the first match?"

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S2: "If the first time I finally found the formula is the following
n + 1 multiplied by 6. "

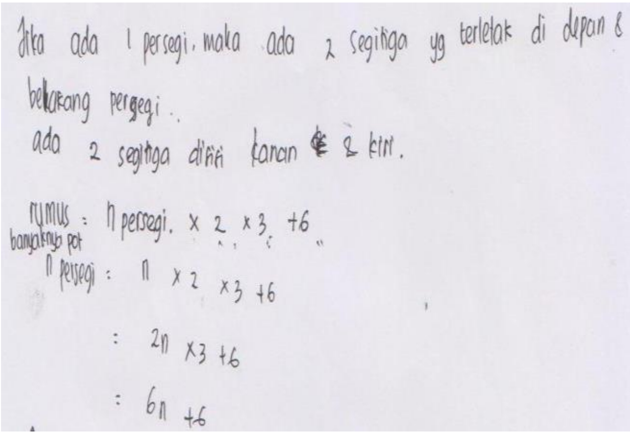
The subject tried several ways to get the right procedure in calculating the number of pots on each model. S2 connects the number of squares with the corresponding operation to be 12 (many pots in model 1), 18 (many pots in model 2) and 24 (many pots in model 3). S2 tried by means of n2 multiplied by 6 but did not match the results (with the number of pots on each model), then tried another way to find the right way, namely the number of squares multiplied by the difference in the number of squares then multiplied by six. The subject found regularity of procedures in determining the number of pots for each model. To determine the number of pots in model 1, that is by means of 1 + 1 × 6 (1 in front shows the number of squares, 1 next to it shows the difference in square on each model, then number 6 shows the number of pots that is increased by six if increasing by 1 square). Likewise in the same way for models 2 and 3, just replace the number 1 in front with 2 and 3 according to the model. In extending actions, S2 extends the range by using the same procedure obtained during searching to be applied to the nth model according to the question in the question. The subject writes for the n square so the number of pots can be calculated by means of n square plus 1 then the result is multiplied by 6.

In the generalization of this global formal correspondence relationship there is a horizontal mathematical process and vertical mathematical process. According to (Wijaya, 2012) the horizontal mathematical process begins with identifying mathematical concepts based on order and relationships found through visualization and schematic problems. Whereas vertical mathematical process is a form of formalization process where mathematical models obtained in horizontal mathematics become the basis for the development of more formal mathematical concepts.

The horizontal mathematical process of generalizing the relationship of formal inductive correspondence can be seen from the search for the regularity of relationships and the transfer of real problems into mathematical models. The subject looks for order and relationship of the model (pattern). The subject sought the order of procedure to calculate the number of pots for each model. The subject connects the quantity of a part (element) model (pattern) 1 to model 2 and model 3. Vertical mathematical processes occur when the subject represents a relation into a formula or rule. This is done by the subject when extending, the subject makes the general rule namely (n + 1) × 6.

The Partial Formal Correspondence Relationship Generalization

Based on the answer of third subject (Figure 3) and results of the aloud, on the action relating the subject connects the parts contained in the model (pattern). The subject finds that if you add one square, there are two triangles located in front of and behind the square. The subject found this information from observing the parts in the picture. The front and back as shown in Figure 4.



Jika ada 1 persegi, maka ada 2 segitiga yg terletak di depan & belakang persegi.
ada 2 segitiga di kanan & kiri.
rumus banyaknya pot : n persegi. × 2 × 3 +6
n persegi : n × 2 × 3 +6
: 2n × 3 +6
: 6n +6

Translate into English:

If there is 1 square then there are 2 triangles located in front and back of the square.
There are 2 triangles on the right and left.

The formula
for the number of pots = $n\ square \times 2 \times 3 + 6$

$$= n \times 2 \times 3 + 6$$
$$= 2n \times 3 + 6$$
$$= 6n + 6$$

Figure 3. The Answer of Third Subject (S3)

The triangle that is located in front and behind the square means, the front is a triangle that is under the square and the back is a triangle that is above the square. In the act of searching, subjects look for pattern regularity based on the number of parts on the model. The subjects found regularity increasing the square, triangle and many pots from models 1, 2 and 3. The excerpt of the interview with the subject.

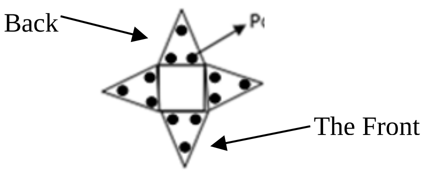


Figure 4. A Model for Placing a Flower Pot

R: "try to explain how you find the regularity of the pattern from the image?"

S3: "Each square increases, there are two triangles located, if there are four ... if there are two squares, there are four and there are ... and if square ... and there are two triangles on the right and left sides (this is the right side and the left side) ... the right and left sides always never change ... never change the amount ... always join"

In extending the subject uses regularity of patterns obtained during searching to determine the number of pots if there are n squares. Based on the model image observed by the subject, because there are two triangles located on the right and left

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side then multiplied by two, multiplied by 3, 3 from one triangle there are 3 flower pots that can be occupied then multiplied by 3 and added 6, 6 from two triangles on the side right and left side. So that many flower pots that can be placed on the nth model are n times 2 times 3 plus 6, 2n multiplied by 3 plus 6 or as much as 6n + 6. The strategy used by the subject is counting form a drawing means counting the components of a specific geometric figure within a pattern (El Mouhayar & Jurdak, 2016).

In the generalization of this global formal correspondence relationship there is a horizontal mathematical process and vertical mathematical process. According to (Wijaya, 2012) the horizontal mathematical process begins with identifying mathematical concepts based on order and relationships found through visualization and schematic problems. Whereas vertical mathematical process is a form of formalization process where mathematical models obtained in horizontal mathematics become the basis for the development of more formal mathematical concepts.

The horizontal mathematical process of generalizing the relationship of partial correspondence can be seen from the search for the regularity of relationships and the transfer of real problems into mathematical models. The subject looks for order and relationship of the model (pattern). The subject looks for pattern regularity by paying attention to the parts of each model. The subject connects the parts contained in the model. Vertical mathematical process occurs when the subject represents a relation into a formula or rule. This is done by the subject when extending, the subject makes a general rule that is $n \times 2 \times 3 + 6$.

The difference between the three groups lies in the strategies used by the subjects. In the global formal correspondence relationship generalization group, subjects observed parts of the pattern image and entered them into a formula to find the n^{th} term. In the inductive formal correspondence relationship generalization group, subjects look for the same rules that apply to known image models and then use them for the n^{th} model. In the partial formal correspondence relationship group, the subject searches for the same rule for a known model based on parts of the model. then used to search for the n^{th} model rule.

Conclusion

Based on the findings, the generalization of correspondence relationships among junior high school students in solving mathematics problems can be categorized into three distinct types: global formal, inductive formal, and partial formal correspondence relationship generalizations. In the global formal type, students engage in relating by analyzing the quantities within the pattern, searching by identifying consistent differences, and extending by applying a general rule using appropriate mathematical formulas. In the inductive formal type, students relate by linking quantities to the model, search by identifying applicable procedures, and extend by generalizing based on repeated procedural similarities. In the partial formal type, students relate by observing specific components of the pattern, search through pattern recognition within subsets of the model, and extend by forming general rules from observed regularities. These findings demonstrate the varied cognitive strategies students use in the generalization process and offer insights into how different levels of abstraction influence students' mathematical reasoning.

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