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Number pattern through realistic mathematics education: A hypothetical learning trajectory

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ABSTRACT

This study developed a hypothetical learning trajectory (HLT) in number pattern material for eighth-grade junior high school students. The methodology consisted of three phases: preliminary design, teaching experiment phase, and retrospective analysis phase. This study focused on the preliminary design, which encompassed various steps such as needs investigations, curriculum analysis, literature studies, and the development of initial prototypes. Moreover, an HLT had been generated through realistic mathematics education. This HLT served as a guiding framework for implementing learning activities and enabled identifying and resolving potential challenges students encountered during the learning process. The identified HLT patterns were utilized as the foundation for designing appropriate learning materials that aligned with the student's learning path, thus, enhancing their overall academic achievement. Furthermore, in this study, the HLT served as a follow-up to the needs analysis based on the findings of the identification process.

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INTRODUCTION

Mathematics is crucial in all facets of existence, extending beyond academia and the professional world. This particular perspective offers fresh perspectives. Despite being perceived as intricate, mathematics undeniably profoundly influences everyday life. Some students encounter challenges when it comes to identifying the principal concept of the problem and formulating abstract generalizations (Fatahillah et al. 2021; Handayani et al. 2015). Algebraic thinking is based on patterns, their relationships, and the generalization of patterns. Put another way, pattern recognition, pattern continuation, and abstraction allow pupils to reason algebraically (Steele 2005). Understanding patterns is essential when transitioning from arithmetic to algebra due to the need to create verbal and symbolic generalizations (Yeúilderea and Akkoçb 2010). Learning about practices can assist students in developing their reasoning abilities (Sari et al. 2018), particularly in the realm of inductive reasoning (NCTM 2000). This subject helps students strengthen their mathematical thinking and bridges the gap between algebraic and arithmetical reasoning (Jupri et al. 2020). Moreover, patterns can serve as a guiding force for students to draw generalizations, a highly significant and practical skill in

KEYWORDS

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solving mathematical problems (Mulligan and Mitchelmore 2009).

The issue of mathematics learning that lacks a connection to everyday life inspires Indonesian mathematics educators to discover new teaching approaches (Laurens et al. 2018; Sembiring et al. 2008). The theory of realistic mathematics education (RME) originated from connecting mathematics with practical applications, giving birth to it. This idea led to its development, as stated by (Uzel and Uyangor 2006). RME aims to make mathematics instruction more enjoyable and significant for students by putting them in context-based issues, which, for many years, has been an interest of many researchers. RME can help pupils think more critically, logically, and creatively. An extremely successful teaching strategy for RME was proposed by a prior study; it involves creating educational resources that are grounded in real-world situations and help students develop their critical thinking abilities (Uyen et al. 2021; Supriyanto and Hairun 2020; Yilmaz 2020; Yuanita et al. 2018; Sumirattana et al. 2017). RME integrated with cultural contexts strives to enable students to acquire mathematical knowledge through their daily experiences and cultural backgrounds.

Henceforth, being an advancement in mathematical education and serving as an application of the Curriculum 2013, which emphasizes the practicality of mathematics in real-life situations and the cultural background of students, researchers using Chinese culture in Tangerang as the starting point or context in learning. Chinese ethnicity is one of the things that colors the diversity in Tangerang City. The Chinese community generally occupies an area called Chinatown Village. One of them is the Chinese community in Tangerang City, known as the Benteng Chinese community (Thresnawaty 2015). The culture found in Chinese culture in Tangerang can be an alternative learning method for studying mathematics.

Wilson et al. (2015) indicate that an educator can enhance the process of student acquisition of knowledge by capitalizing on their pre-existing understanding by utilizing a pedagogical method known as learning trajectories. A learning trajectory serves as a guide or framework to be utilized as a point of reference for formulating learning strategies in every learning endeavor. Teachers are faced with determining the most effective approach to structuring and implementing schemes to facilitate optimal student learning. Hypothetical learning trajectories (HLT) are a valuable tool to guide the thought process behind task organization to enhance student learning (Zahner and Wynn 2021; Moss and Lamberg 2019).

Simon and Tzur (2004) contended that a hypothetical learning trajectory (HLT) consists of three fundamental elements: (i) educational goals, (ii) instructional activities employed to construct students' understanding, and (iii) assertions about the course of the learning activities. These elements entail anticipating the development of students' thoughts and comprehension within the context of the instructional activities. During the preliminary design phase, HLT guides the development of teaching materials. Furthermore, in the course of teaching trials, the HLT proved to be a valuable tool for educators and researchers engaged in the facilitation of teaching activities, interviews, and observations (Prahmana and Kusumah 2016). In contrast to prior studies, the objective of this research is to formulate an HLT centered around the learning of number patterns, with the Chinese culture in Tangerang City serving as both the point of origin and the contextual backdrop for the learning process. This research introduces a novel aspect in the form of a theoretical learning trajectory. This trajectory serves as the foundation for creating RME with cultural context-based learning designs, exploring a cultural context that has not been previously investigated in the realm of mathematics. Additionally, the study considers the unique conditions of the school under examination, influenced by the adopted culture, to enhance the depth of the learning process and its outcomes. These innovations can be put into practice during implementation.

MATERIALS AND METHODS

This study employed design research methodology as the appropriate approach to address research questions and fulfill research objectives. This involved progressing through stages that included preliminary design, teaching experiments, and retrospective analysis (Suparman and Maryati 2019; Maryati and Prahmana 2019). Design research was a methodology characterized by five distinct features: an interventionist quality, a process-focused methodology, a reflective element, a cyclic nature, and a framework oriented toward theory (Prahmana and Kusumah 2016). Design research encompassed two important elements: the HLT and the local instruction theory (LIT). Design research epitomized a cyclical process whereby thought experiments and instructional experiments were conducted to facilitate implementation (Gravemeijer 2004). The subjects in this research were 34 students from class IX Junior High School in Tangerang. The analysis of data in this study involved a comparison between the observed results during the learning process and the HLT designed in the preliminary design stage. The evolution of learning design occurred through three stages: preliminary design, design experimentation, and retrospective analysis.

The primary objective of the preliminary design stage was to create a set of learning activities and design tools for assessing the learning process. In this study, a review of the literature was conducted on the mathematics curriculum, number pattern material, and RME to formulate hypotheses or assumptions about student thinking. During this phase, the HLT was structured to be transformed into learning objectives and instructional materials. In this scenario, the conjecture acted as a guiding principle that emerged and evolved in each learning activity. It was adaptable and could be modified during the experimental design or testing stage. The design experiment stage was trying out the learning trajectory created in the learning process. This stage explored and predicted students' strategies and thinking during the learning process. In Retrospective Analysis, HLT estimations were compared with the results of the experimental design stage. From the results of this analysis, a picture of the learning trajectory in learning with the Chinese cultural context in Tangerang could be produced.

RESULTS AND DISCUSSION

Trends in RME research in Scopus journals from year to year are increasingly visible as bibliometric results in research conducted by Phan et al. (2022) regarding RME trends between 1972 and 2019. Bibliometric analysis continues to evolve with technological advances, incorporating new metrics and visualization techniques that enhance its utility (van Eck and Waltman 2010; Aria and Cuccurullo 2017).

As the volume of academic publications grows exponentially in the digital age, the significance of bibliometric analysis in guiding research strategy, evaluating scholarly impact, and

understanding knowledge development becomes increasingly paramount, making it an indispensable tool in modern academic research and evaluation (Leydesdorff and Rafols 2009). The bibliometric results obtained until 2024 are shown in **Figure 1**.

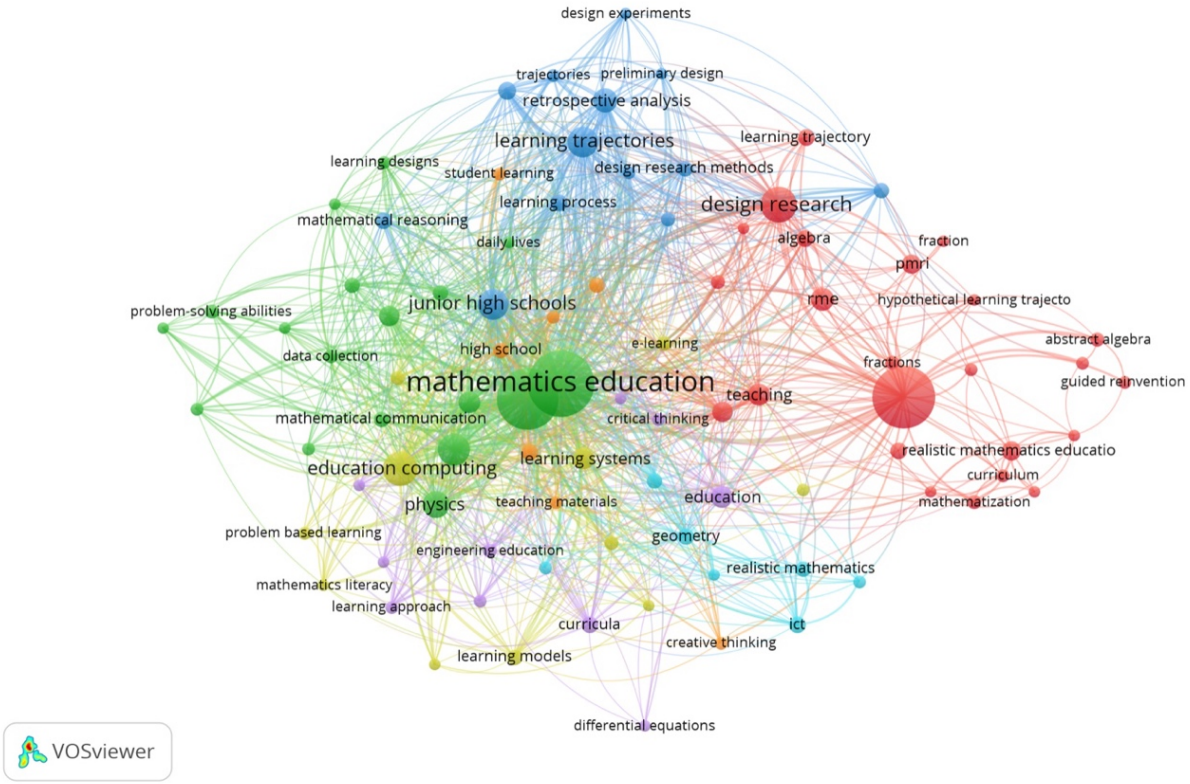


Figure 1: Network visualization of most-occurring keywords

Based on Figure 1, RME is a small part that is still being researched and one of the subjects taught in this RME learning is algebra in which there is number pattern material. The innovation in RME learning is the utilization of real-world contexts by combining cultural elements consisting of mathematical concepts and sociocultural values, which can encourage the development of positive character in students. (Prahmana et al. 2023; Rosa and Orey 2015; D'Ambrosio 2007). Material that can be used in RME learning in junior high school is number pattern material.

A number pattern is a sequence of numbers or an arrangement of numbers that form a certain pattern. From the arrangement of numbers that form a pattern, a general formula is obtained to determine the n-th term of a number pattern. Number patterns are materials that can be seen in everyday life, for example in the process of cell division of the body called Mitotic. The pattern contained in this mitotic process is a pattern multiplied by two. At first, the cell is only one, then divides into two, becomes four, eight, and so on. If formed in a series of numbers it obtains a pattern of 1, 2, 4, 8, 16, 32, 64, 128, 256, and so on. The mitotic process can be seen in Figure 2.

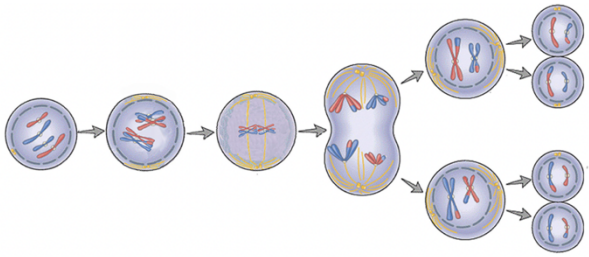


Figure 2: Stages of mitotic (Hansen and Richlan 2020)

In the learning process, to help teachers identify gaps in understanding and misconceptions that may occur in learning number pattern material, a hypothetical HLT is needed. Teachers can use this HLT as a benchmark to evaluate how well their students comprehend numerical patterns and to assist them in organizing a reasonable lesson plan. HLT supports the transition from concrete to abstract comprehension of the idea of number patterns and aids in the progressive development of conceptual understanding of these patterns.

The validation of the HLT was conducted through evaluation by three experts in mathematics education who were familiar with the RME approach. After engaging in discussions and revision processes with these experts, the HLT successfully fulfilled the validity criteria. Some of the criteria approved by the experts included: (i) the contextual problems presented to students had the potential to assist in their conceptual reimagining of number patterns; (ii) the learning activities devised for students could guide them through the process of both horizontal and vertical mathematization; (iii) the HLT demonstrated characteristics suitable for instructional design, teaching, and learning; (iv) the HLT exhibited promise in improving students' reasoning abilities in the study of number patterns. The outcomes of this research materialized in the form of an HLT design, presenting a learning sequence tailored for junior high school level translation learning within the Chinese cultural context in Tangerang. We elaborate on the outcomes of the learning procedure in mathematics education. This investigation is categorized into three phases: preliminary design, teaching experiments, and retrospective analysis.

In the preliminary design stage, we implemented the problem by explaining the number pattern material related to object

configuration and introducing a little about batik in Peranakan Chinese culture. In this activity, one class is divided into 8 groups, each group consisting of 4-5 students. Each activity carried out in HTL 1 has its objectives. The first activity is introducing problems through objects around the school that are used for research that students can see every day and introducing a little about drawings of Peranakan Chinese batik patterns, where problems are taken from everyday life that relate to possible number pattern material. Experienced by students. The Chinese cultural context in Tangerang in number pattern material. Developing HLT in every learning activity is crucial in designing student learning activities. Design must be distinct from the learning trajectory, which contains learning plans for the material being taught. In this case, the learning trajectory is a concept map for students. It goes through during the learning process. The learning trajectory used in this research is understanding the concept of number patterns through Chinese culture in Tangerang. The process begins by explaining Chinese culture and its relationship with the implementation of number pattern material. This process gained an understanding of the relationship between culture and the material to be taught. The process can be seen in **Figure 3**.

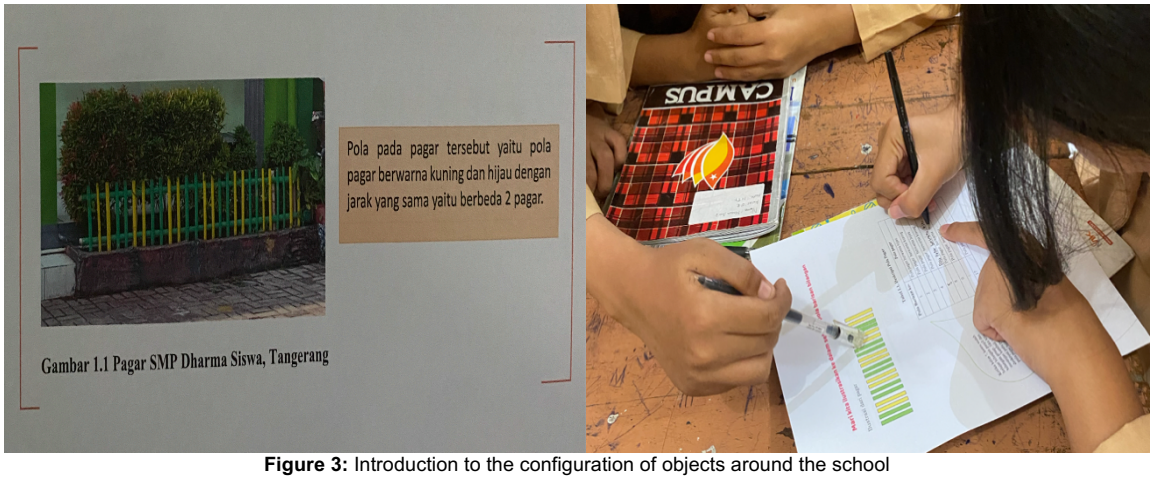


Figure 3: Introduction to the configuration of objects around the school

Activity 1. In this student activity, students are expected to be able to understand the configuration of objects and what kind of patterns can form in objects around them. The starting point is easier for students if they know what kind of pattern can be formed from the object in question. During this task, students are prompted to respond to questions posed by the teacher, and they have the opportunity to hear the teacher's explanation regarding the arrangement of objects on the school fence. Students observe pictures in teaching materials, students can guess what kind of pattern can be formed in the fence. After students know the pattern formed, they are directed to solve several questions in the teaching materials and can find out what kind of pattern is formed. We guessed that the students answered questions from the teacher and the students made observations on the patterns contained in the fence, the students began to guess the patterns related to the configuration of the objects. After carrying out this activity, according to our expectations in stage 1, many students could answer questions correctly regarding what kind of pattern was formed in the fence. The retrospective analysis of this activity is based on some data contained in the teaching materials, students have achieved the learning objectives related to the activity of answering the question. The following are students' answers to activity 1, as can be seen in **Figure 4**.

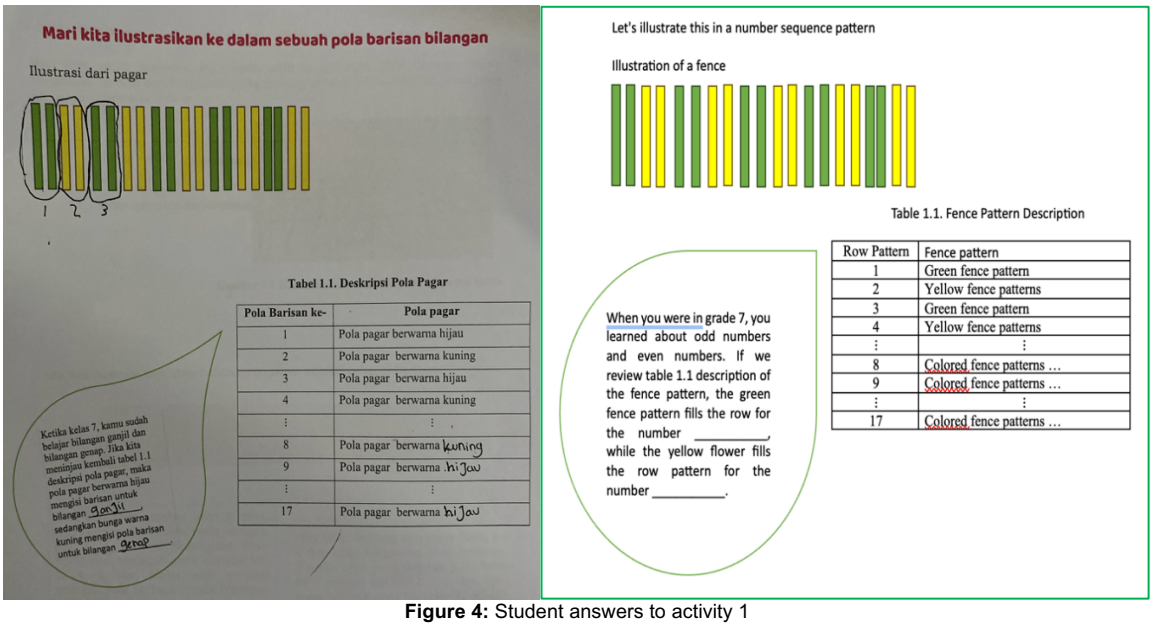
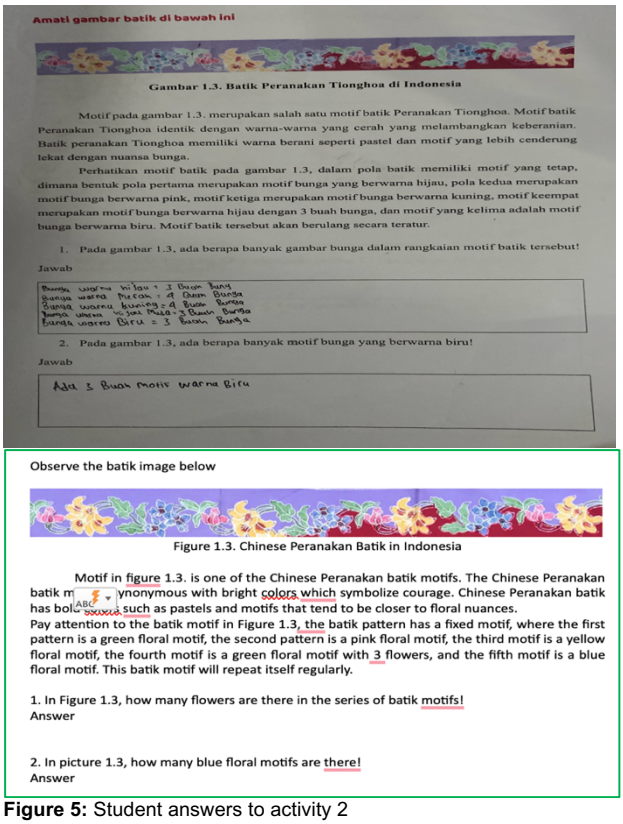


Figure 4: Student answers to activity 1

In the next activity, students were introduced to Peranakan Chinese batik. In this batik, several patterns were formed. Students knew what patterns are in this batik. After carrying out the activities in activity 1, students are expected to be able to answer the patterns formed in Peranakan Chinese batik, as well as describe the next pattern that is formed. In this process, some students forgot how to calculate the nth term of a pattern. Others were confused about determining the next pattern in the series of batik motifs and had difficulty applying batik-related questions to the formula for a flat plane. The methods and answers in the calculations that students carry out are debated between group members because there are misperceptions and errors in the calculation process. The following are the results of students' answers to activity 2 can be seen in **Figure 5**.


Amati gambar batik di bawah ini

Gambar 1.3. Batik Peranakan Tionghoa di Indonesia

Motif pada gambar 1.3. merupakan salah satu motif batik Peranakan Tionghoa. Motif batik Peranakan Tionghoa identik dengan warna-warna yang cerah yang melambangkan keberanian. Batik peranakan Tionghoa memiliki warna berani seperti pastel dan motif yang lebih cenderung lekat dengan nuansa bunga.

Perhatikan motif batik pada gambar 1.3, dalam pola batik memiliki motif yang tetap, dimana bentuk pola pertama merupakan motif bunga yang berwarna hijau, pola kedua merupakan motif bunga berwarna pink, motif ketiga merupakan motif bunga berwarna kuning, motif keempat merupakan motif bunga berwarna hijau dengan 3 buah bunga, dan motif yang kelima adalah motif bunga berwarna biru. Motif batik tersebut akan berulang secara teratur.

1. Pada gambar 1.3, ada berapa banyak gambar bunga dalam rangkaian motif batik tersebut!

Jawab

2. Pada gambar 1.3, ada berapa banyak motif bunga yang berwarna biru!

Jawab

Ada 3 Buah motif warna Biru

Observe the batik image below

Figure 1.3. Chinese Peranakan Batik in Indonesia

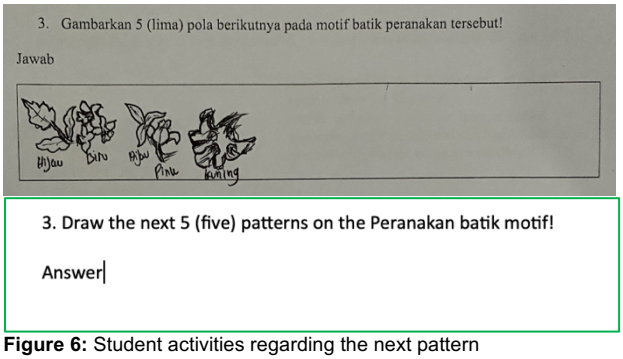
Motif in figure 1.3. is one of the Chinese Peranakan batik motifs. The Chinese Peranakan batik m ynonymous with bright colors which symbolize courage. Chinese Peranakan batik has bol such as pastels and motifs that tend to be closer to floral nuances.
Pay attention to the batik motif in Figure 1.3, the batik pattern has a fixed motif, where the first pattern is a green floral motif, the second pattern is a pink floral motif, the third motif is a yellow floral motif, the fourth motif is a green floral motif with 3 flowers, and the fifth motif is a blue floral motif. This batik motif will repeat itself regularly.

1. In Figure 1.3, how many flowers are there in the series of batik motifs!
Answer

2. In picture 1.3, how many blue floral motifs are there!
Answer

Figure 5: Student answers to activity 2

After completing activity 2, students then carry out activity 3, As for. Students' answers to activity 3 are in Figure 6. In this activity, students see the patterns that appear in Peranakan batik, students are required to write the next pattern from the part that appears in the batik pattern. After being guided, the students were finally able to describe the next pattern although some students were still confused about the answer. After being asked and answered, information was obtained that students were confused about what kind of pattern emerged. Students must be guided and given supporting examples to find the answer. The activity in this phase is crucial in serving as a connection for comprehending the notion of numerical sequences from the structured degree to the unstructured degree. We did not directly show what patterns could emerge next. Thus, students can construct their knowledge. After students get the pattern correctly, they have not yet answered the question "Why did this pattern appear". We reminded students to read again and answer questions that students had not answered. The answer to activity 3 can be seen in **Figure 6**.


3. Gambarkan 5 (lima) pola berikutnya pada motif batik peranakan tersebut!

Jawab

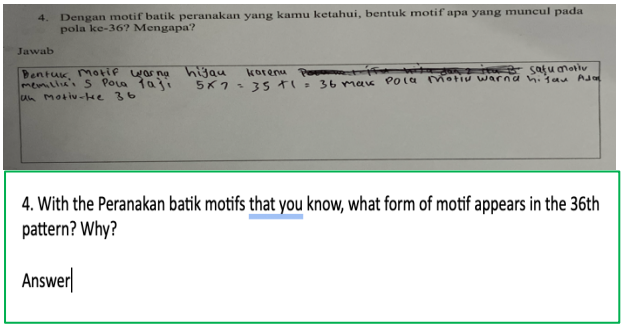
Hijau Biru Pink Kuning

3. Draw the next 5 (five) patterns on the Peranakan batik motif!

Answer

Figure 6: Student activities regarding the next pattern

After students understand what kind of pattern can be created next, the next activity is to answer questions about the nth term. In this activity, the teacher asks what strategies the students know to answer the question. All students answered simultaneously using the same method, namely by counting them. From this question, students answer manually by counting the patterns that appear in each term one by one. This takes a lot of time if the term being asked is a very high-value term. We tried to stimulate students to work in ways that comply with the rules of number patterns. Initially, the students had difficulty understanding this method, but slowly the students were able to understand it and explain it to their group friends. After knowing how to solve it, students are asked to answer the questions in the teaching materials and state the reasons for getting the answers. Of all the students, only two groups expressed their opinions and the other group only answered the nth term pattern, and did not express their opinions. This is a concern to stimulate students by providing reasons for the answers they have made. The answer to activity 3 can be seen in **Figure 7**.


4. Dengan motif batik peranakan yang kamu ketahui, bentuk motif apa yang muncul pada pola ke-36? Mengapa?

Jawab

Bentuk motif warna hijau karena ... satu motif ... 5 pola ... 5×7 = 35 +1 = 36 maka pola motif warna hijau ... motif ke 36

4. With the Peranakan batik motifs that you know, what form of motif appears in the 36th pattern? Why?

Answer

Figure 7: Student activities regarding the next pattern

The next activity is for students to be faced with a problem that combines a number pattern with the area of an object. Almost all students were confused in answering this question. We guided students to connect the concept of number patterns with the concept of the area of an object and see the results of their answers so they can use the concept of number patterns for the next question. After being given anticipation, students solve the problem using the concept of calculations on number patterns and the area of objects to obtain answers as in **Figure 8**.

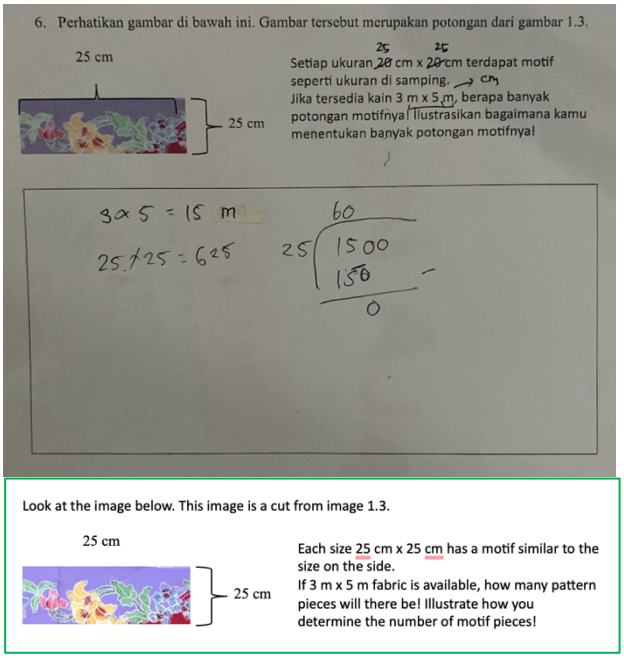


Figure 8: Student answers to activity 4

At this experimenting stage, the assumptions that have been made at the initial stage appear to be implemented even though some of the student's cognitive processes are beyond expectations. Arguments from several student group representatives show that there are two student understandings regarding the calculation method in the question above. Of the 8 groups, three groups did not understand the meaning of the question at all. Meanwhile, five groups already understand how to solve it. In the third activity, some students even got the idea to multiply and then divide by each length of fabric available. During class learning, it appeared that some students were not active in the discussion process, but we tried to encourage these students to communicate so that they remained active in discussing with their group friends. In the activity of listening to the teacher's directions and explanations, it appears that all students are active. RME using cultural context is one solution to help students understand learning material. RME provides students with the opportunity to learn through other students. Other studies (Prahmana 2022) research on the integration of cultural context in mathematics and its application in practical situations has the potential to alter the negative perception held by students and society towards mathematics. Errors may arise if students engage in incorrect computations, such as when determining the pattern that manifests in the nth sequence. To incorporate design into the pedagogical process, educators have the opportunity to motivate students to employ various strategies. Rather than relying solely on manual calculations, students can first analyze the underlying rules and subsequently perform the necessary computations. By adopting this approach, the occurrence of potential errors can be mitigated. For instance, students can be encouraged to conduct a final assessment by computing the patterns that manifest in subsequent sequences. After the implementation of the individualized task by all the students, we acquired the findings that the students were able to proficiently resolve the given problems. The students were capable of comprehending the presented material and adhering to all the activities encompassed within the textbook. Furthermore, the subject matter of the problems within the student book also engrossed the students. By highlighting the presence and relevance of mathematics in everyday life, this approach effectively demonstrates that mathematics is an integral part of societal culture.

CONCLUSION

From the research findings, it can be inferred that HLT holds significant importance for educators in the development of learning trajectories as a point of reference when designing instructional approaches that can optimize students' abilities in comprehending number patterns, particularly in the realm of object configuration. However, it is important to acknowledge that in this study, the aforementioned conclusion cannot be divorced from the challenges encountered by students throughout the entire learning process, ranging from initial initiation to the retrospective stage. The proposal put forth underscores the significance of the teacher's preparatory phase in equipping themselves with appropriate teaching materials to enhance students' grasp of the subject matter about number patterns. Furthermore, employing teaching materials within the framework of the RME approach is considered crucial to enhance students' understanding. Additionally, the teacher's guidance throughout the learning process is indispensable for students to achieve the intended learning trajectory. The comprehension of the number pattern concept by the students was facilitated due to its enjoyable nature and notably, subsequent engagement in various educational exercises. Ultimately, the game also establishes a connection with their routine activities. It is our aspiration that future research delves into the topic of number pattern material employing the RME approach, albeit within a different context, while considering HLT as a point of reference for understanding students' cognitive processes and the construction of the concept of number patterns.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

CONTRIBUTIONS OF INDIVIDUAL AUTHORS

RSF Iskandar: Conceptualization, prepared the relevant literature and overlooked the writeup of the whole article, Editing, and Visualization. Darhim: performed revised critically for important intellectual content. JA Dahlan: Validation and Supervision. Al Jupri: Writing-Review and Editing, Formal Analysis, and Methodology.

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