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DESIGN LEARNING OF ARITHMETIC SEQUENCE USING STAIR CONTEXT TO SUPPORT STUDENTS' CONCEPTUAL UNDERSTANDING

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Abstract

This study aimed to develop an arithmetic sequence learning design based on the Indonesian Realistic Mathematics Education (PMRI) approach using a stair context to enhance students' conceptual understanding. The research employed a design research methodology consisting of three phases: preliminary design, design experiment, and retrospective analysis. The participants were grade 10 students at MA Al-Ittifaqiah Indralaya, and Student Activity Sheets (SAS) were designed according to PMRI principles. Findings indicate that the stair context effectively supported students in identifying arithmetic sequence patterns concretely. Initially, students were able to observe and record stair height patterns and recognize the common difference. However, many struggled to generalize the formula in symbolic form, even though they could compute patterns for large cases such as the 901st or 2001st stair. This led to revisions in the SAS by simplifying symbols and questions and emphasizing concrete language. The revised design eliminated confusing symbols, reduced repetitive problems, and applied a gradual approach to connect concrete patterns with formal notation. The study concludes that while the PMRI approach improves students' conceptual understanding of arithmetic sequences, additional support is needed to strengthen their symbolic reasoning. These results contribute to developing contextual and effective mathematics learning designs relevant to students' needs.

Keywords: arithmetic sequence, PMRI, stair, design research, formal symbols

Abstrak

Penelitian ini bertujuan mengembangkan desain pembelajaran barisan aritmatika berbasis Pendidikan Matematika Realistik Indonesia (PMRI) dengan konteks tangga untuk mendukung pemahaman konseptual siswa. Metode yang digunakan adalah design research dengan tiga tahap utama: perancangan awal, eksperimen desain, dan analisis retrospektif. Subjek penelitian adalah siswa kelas X MA Al-Ittifaqiah Indralaya, dengan Lembar Aktivitas Siswa (LAS) yang dirancang berdasarkan prinsip PMRI. Hasil penelitian menunjukkan bahwa konteks tangga efektif membantu siswa mengenali pola barisan aritmatika secara konkret. Pada awalnya siswa mampu mengamati dan mencatat pola tinggi tangga serta selisih tetap antartangga. Namun, sebagian besar siswa mengalami kesulitan menyusun rumus umum dalam bentuk simbol formal, meskipun mereka mampu menghitung pola untuk kasus kompleks seperti tangga ke-901 atau ke-2001. Hal ini mendorong revisi LAS untuk menyederhanakan simbol dan pertanyaan serta menggunakan bahasa yang lebih konkret. Revisi desain meliputi penghapusan simbol yang membingungkan, pengurangan soal berulang, dan penerapan pendekatan bertahap untuk menghubungkan pola konkret dengan notasi formal. Penelitian ini menyimpulkan bahwa pendekatan PMRI efektif meningkatkan pemahaman konsep barisan aritmatika, tetapi kemampuan siswa dalam representasi simbolik masih memerlukan pendampingan lebih lanjut. Temuan ini berkontribusi pada pengembangan desain pembelajaran matematika yang kontekstual dan sesuai kebutuhan siswa.

Kata kunci: barisan aritmatika, PMRI, anak tangga, design research, simbol formal

INTRODUCTION

Education plays a pivotal role in preparing Indonesia's future generations by developing critical thinking and problem-solving skills to address global challenges and contribute positively to society (Sulistiani & Masrukan, 2017). According to Hidayat (2021), strengthening character education is an urgent strategy to create intelligent, resilient individuals capable of

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meeting 21st-century demands. The 1945 Constitution establishes education as the foundation for national development, emphasizing the need for a high-quality system that fosters both competence and nationalism. However, despite advancements, challenges persist in terms of access, quality, and relevance to labor market needs (Muiz et al., 2024). These issues require education policies that ensure effectiveness and equity, supported by technological innovations and progressive approaches.

Mathematics plays a critical role in enhancing students' analytical and logical reasoning (Ulya et al., 2019). Through innovative methods, such as Realistic Mathematics Education (RME), students' representational skills can be strengthened. Mathematics is not limited to numerical computation but serves as a foundation for logical and analytical thinking. Nevertheless, mathematics education in Indonesia continues to face challenges, particularly in delivering quality learning that aligns with students' needs.

Based on PISA 2022, Indonesia ranks 70th globally in mathematical literacy, indicating significant gaps in conceptual understanding (Zamroni et al., 2024). Students often face difficulties due to limited exposure to varied teaching strategies, overemphasis on rote learning, and insufficient practice tailored to their needs (Susilawati, 2015). These conditions hinder their ability to apply concepts in real-life situations. Disparities in educational resources between urban and rural areas further exacerbate these problems (Susianita & Riani, 2024). Therefore, innovative learning approaches are essential to improve both understanding and engagement in mathematics.

The primary challenge in mathematics education lies in helping students comprehend abstract concepts (Zahar, 2021). Many students perceive mathematics as difficult, complicated, and uninteresting, which affects their motivation to learn. This negative perception often stems from traditional teaching practices and the misconception that mathematics is relevant only for those pursuing careers in exact sciences. To overcome these barriers, contextual and engaging learning approaches are necessary.

Lestariningsih (2018) compared students' performance on arithmetic sequences using problem-based learning and conventional lectures. Findings revealed that problem-based learning significantly improved conceptual understanding by actively engaging students in problem-solving, fostering critical and analytical thinking skills. This suggests the need for active learning strategies in mathematics instruction.

Similarly, Dewi, Kinanti, and Sulistyorini (2020) examined arithmetic patterns in the rhythmic structures of Gending Ketawang in Yogyakarta gamelan. Their study demonstrated the integration of mathematical concepts within cultural practices, highlighting the potential of ethnomathematics for contextual learning. Such approaches provide meaningful connections between mathematics and real-life experiences.

Given these conditions, the Realistic Mathematics Education (RME) approach emerges as a promising solution. The Indonesian adaptation, known as Pendidikan Matematika Realistik Indonesia (PMRI), is based on two principles: (1) mathematics must be connected to real-life contexts, and (2) learning is viewed as a human activity involving exploration and problem-solving (Zulkardi et al., 2020). PMRI emphasizes contextualized learning activities, enabling students to construct mathematical concepts through meaningful engagement (Zaini & Marsigit, 2014; Astuti, 2018).

Arithmetic sequences represent one of the more challenging yet relevant topics in mathematics. These sequences involve patterns that can be difficult for students to understand without concrete representations (Liberna & Seruni, 2021). Although commonly applied in daily life (Annisa & Kartini, 2021), the abstract nature of the topic often creates learning difficulties. To address this, the present study employs the context of stairs in designing Student Activity Sheets (SAS) aligned with PMRI principles. This context aims to provide meaningful learning experiences that support students in transitioning from concrete observations to formal symbolic representations.

Previous studies have applied contextual approaches such as ethnomathematics (e.g., traditional music and cultural artifacts) and real-life scenarios (e.g., cooking measurements, shopping activities) to support conceptual understanding (Dewi et al., 2020; Zahar, 2021; Lestariningsih, 2018). While these contexts provide cultural and practical relevance, the stair context offers a simple, familiar, and visually structured representation, making it effective for illustrating the additive structure of arithmetic sequences. This study contributes by demonstrating how this context, when combined with PMRI principles, can facilitate students' transition from concrete experiences to formal notation.

METHODS

This study employed a design research methodology to develop arithmetic sequence learning based on the PMRI approach using a stair context in the form of Student Activity Sheets (SAS) for senior high school students. The type of design research applied was validation studies, aiming to improve the effectiveness of mathematics learning through a contextual approach. According to Prahmana (2017), design research consists of three main phases: preliminary design, design experiment, and retrospective analysis.

The preliminary design phase began with a literature review on arithmetic sequences, PMRI principles, the kurikulum merdeka, and design research concepts. This review informed the development of the Hypothetical Learning Trajectory (HLT), which included learning objectives, activities, and supporting tools presented in the SAS. The HLT served as a conjecture to predict students' possible strategies and understanding during learning, allowing for adjustments during the experiment phase. The SAS and HLT were validated by one lecturer who teaches PMRI courses and two senior high school mathematics teachers. The validation focused on contextual relevance, alignment with learning objectives, clarity of instructions, and adherence to PMRI principles. Minor revisions were made based on expert feedback, including simplifying instructions and removing ambiguous symbols. After these adjustments, the instruments were declared suitable for implementation.

The design experiment phase comprised two stages: a pilot experiment and a teaching experiment. The pilot experiment involved six students, focusing on testing the initial HLT design. Students received brief instructions on using the SAS before completing it independently. Data from this stage were used to revise the HLT for the teaching experiment. In the teaching experiment, the revised HLT was implemented with the research class, where the researcher facilitated discussions, addressed students' questions, and observed learning activities.

The retrospective analysis phase aimed to analyze data from both experiments to refine the HLT and learning design. At this stage, the initial HLT was compared with actual learning trajectories observed in the classroom. The analysis provided insights for improving the learning design and answering the research questions.

Figure 1. Design Research Phase

The study was conducted with 15 grade 10 students from MA Al-Ittifaqiah Indralaya. Data were collected through SAS responses, observations, and interviews. Observations were conducted during learning activities, while interviews were used to clarify students' reasoning and gather additional information not captured during class. All data were analyzed qualitatively using descriptive techniques to produce a more effective HLT aligned with PMRI principles.

RESULTS AND DISCUSSION

1. Preliminary Design

In the initial phase, the researcher observed the research site at MA Al-Ittifaqiah Indralaya to identify conditions relevant to the study. The school implements the kurikulum merdeka, and arithmetic sequences are taught in the first semester of grade 10. Based on this, the topic was selected for the study, and the stair context was chosen as it aligns with PMRI principles.

A Hypothetical Learning Trajectory (HLT) was then designed, consisting of learning objectives, activities, and conjectures about students' strategies (Prahmana, 2017). The HLT presented in Table 1 reflects the revised design after major adjustments based on the pilot experiment. The initial HLT served as the basis for the pilot experiment, but revisions were necessary to better align the learning trajectory with students' actual responses. These revisions aimed to improve clarity, simplify symbols, and strengthen the scaffolding toward formal notation.

The revised HLT and the Student Activity Sheet (SAS) were validated by experts as described in the Methods section. This validation ensured the appropriateness of the objectives, activities, and PMRI principles applied in the design. Both the HLT and SAS were declared suitable for implementation after minor revisions based on expert feedback. Table 1 presents the validated HLT design.

Table 1. HLT Design

Objective	Activities	Conjectures
Understand the context of stairs and identify patterns	**Activity 1:** Observing the Stair – Students observe a stair illustration and discuss its features.	Students recognize that stair heights form an increasing pattern and predict how this pattern might continue.
Recognize the structure of arithmetic sequences	**Activity 2:** Recording Stair Heights and Recognizing Patterns – Students complete a table of stair heights from 1st to 7th step.	Students notice the systematic increase in height and begin to see regularity in the pattern.
Identify the common difference between terms	**Activity 3:** Identifying the Constant Difference – Students calculate differences between consecutive stairs and verify consistency.	Students understand the concept of constant difference and relate it to the definition of arithmetic sequences.
Transition from concrete to symbolic representation	**Activity 4:** Developing a General Formula Using Simplified Language – Students formulate a general rule using familiar terms (e.g., "last stair minus one").	Students construct informal generalizations without relying on abstract symbols like *n-1*, showing conceptual progress.
Apply generalization to complex problems	**Activity 5:** Applying the Pattern to Large Numbers – Students calculate heights for stairs such as the 901st or 2001st.	Students apply reasoning based on earlier generalization, even if expressed verbally, to solve large-number cases.

2. Design Experiment

This phase consisted of two stages: the pilot experiment and the teaching experiment.

a. *Pilot Experiment*

The pilot experiment involved six students completing an SAS consisting of five activities with 29 questions. These questions progressed from simple pattern recognition to complex tasks involving large stair numbers. The purpose was to test the effectiveness of the initial HLT design.

Activity 1 (Stair Pattern Observation)

The Student Activity Sheet (SAS) begins with Activity 1, where students are asked questions designed to introduce patterns. This activity involves filling in a table and explaining the pattern formed from the data.

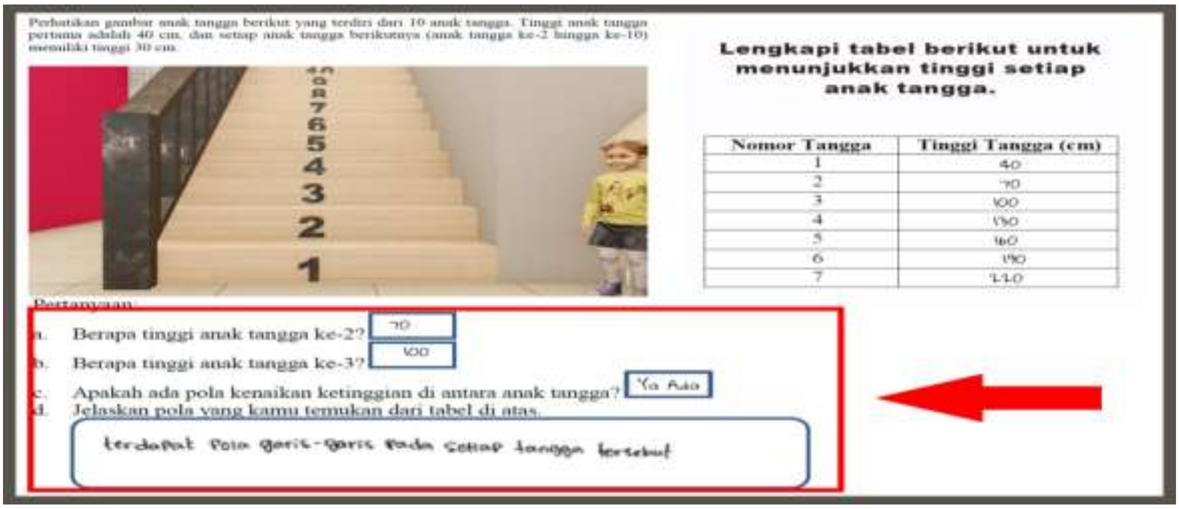

Figure 2. Stair Pattern Observation

Students observed stair illustrations and recorded patterns in a table. Redundant questions were removed after feedback, as they did not contribute to the learning objectives (Figure 2).

Activity 2 (Recognizing the Difference)

Activity 2 is designed to ask students to determine the difference between the height of one stair and another adjacent stair. In this activity, students are presented with blank boxes that must be filled in according to the pattern of stair heights based on the difference between each successive stair. After completing the filling of the boxes, students are asked some related questions to test their understanding of the concept.

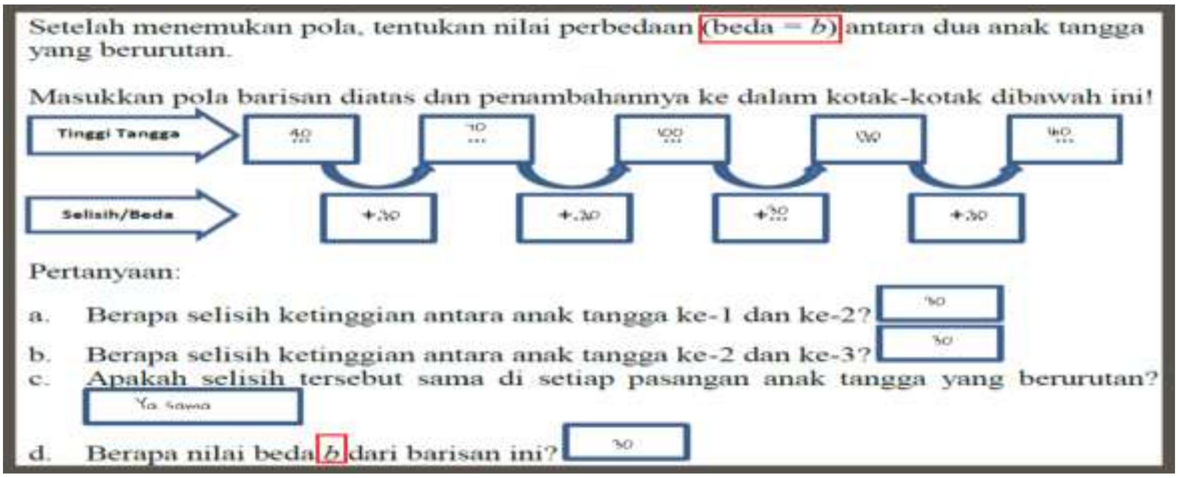

Figure 3. Recognizing the Difference

Students calculated and confirmed the constant difference between stair heights. This activity effectively met its goal, but symbols such as b were removed for clarity (Figure 3).

Activity 3 (Constructing the Formula)

In Activity 3, students are asked to construct a formula for the height of stairs by observing a picture of a child named Andi who is climbing stairs. In this activity, students are asked to look at the picture and use it as a reference to determine the height of each stair. Furthermore, students are asked to answer questions that are arranged in accordance with the context of the picture, so as to encourage their understanding of the concepts learned.

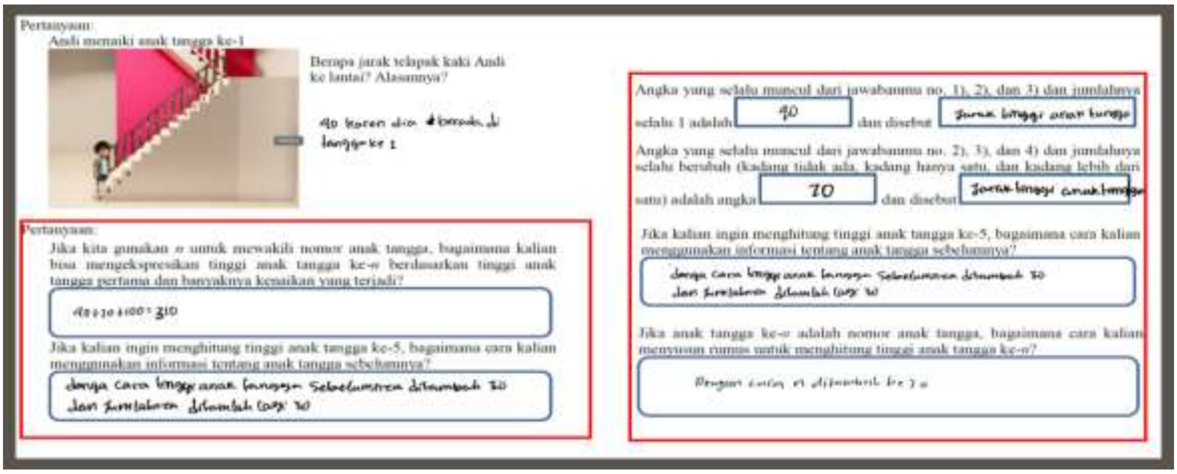

Figure 4. concrete language

Students attempted to formulate a general rule for stair heights. Many faced difficulties with symbolic representations, such as n, leading to revisions that emphasized concrete language (Figure 4).

Activity 4 (Applying the Formula)

Activity 4 is designed to lead students to apply number patterns in the formal domain. At this phase, students are asked to calculate the height of the stairs directly using the formula they have found before.

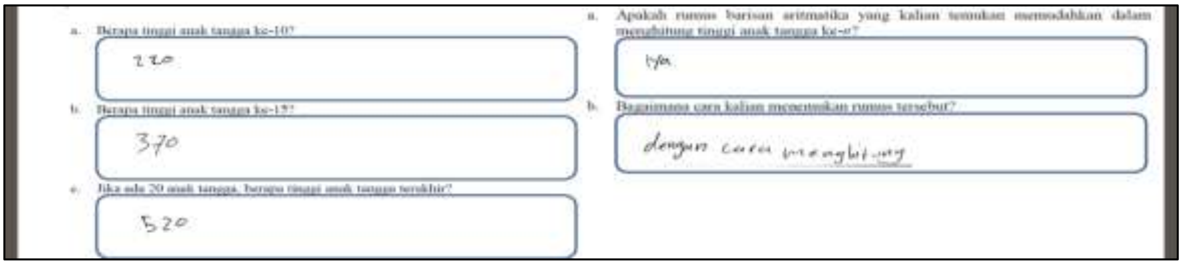

Figure 5. revision

Although designed to apply general formulas, most students relied on manual addition instead of symbolic methods. This activity required major revision (Figure 5).

b. *Teaching Experiment*

The teaching experiment involved 15 students working in five groups, each completing the revised SAS containing five activities. The improvements made after the pilot experiment included reducing repetitive questions, removing abstract symbols (n, Un, b), and introducing an observation-based opening activity. These changes aimed to strengthen conceptual understanding and gradually build symbolic reasoning.

Activity 1 (Observing the Stair)

Students observed an illustration of stairs as the initial context. This activity aimed to develop familiarity with the real situation before moving toward abstraction (Figure 6).

Figure 6. toward abstraction

Activity 2 (Recording Stair Heights and Recognizing Patterns)

Students filled in a table listing stair heights sequentially from the 1st to the 7th stair. The purpose was to help students recognize number patterns systematically (Figure 7).

Mengenali Pola

Amati ketinggian anak tangga.

1. Lengkapi tabel berikut untuk menunjukkan tinggi setiap anak tangga.

Nomor Tangga	Tinggi Tangga (cm)
1	40
2	70
3	100
4	130
5	160
6	190
7	220

Figure 7. patterns systematically

Activity 3 (Identifying the Constant Difference)

Students calculated the height difference between consecutive stairs and confirmed whether the difference was constant. This activity introduced the core concept of arithmetic sequences through a concrete pattern (Figure 8).

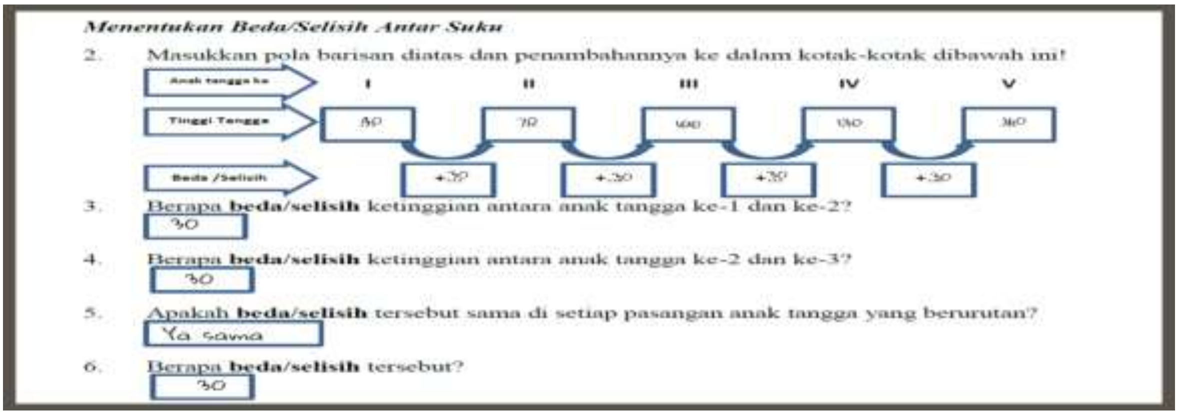

Figure 8. concrete pattern

Activity 4 (Developing a General Formula Using Simplified Language)

Students were guided to formulate a general rule without using abstract symbols. Instead of using expressions like n-1, students employed simpler phrases such as “last stair minus one” to connect concrete observations with formal reasoning (Figure 9).

Figure 9. formal reasoning

Activity 5 (Applying the Pattern to Large Numbers)

Students solved problems involving large stair numbers, such as the 901st and 2001st stairs. Although most students could compute the values logically, they continued to struggle with symbolic notation (Figure 10).

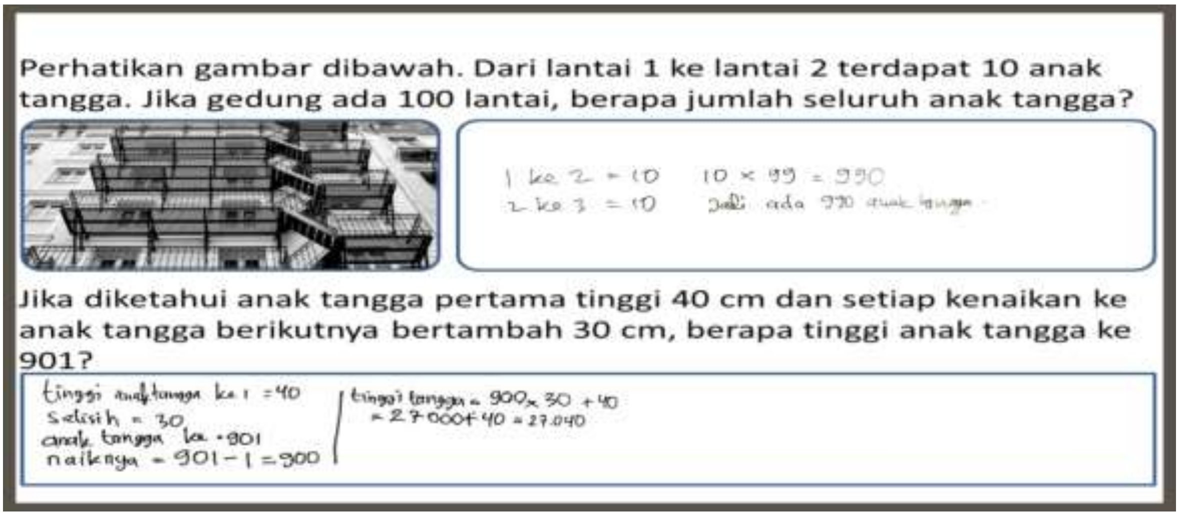

Figure 10. symbolic notation

To gain deeper insight into students' reasoning and the challenges they faced in symbolic representation, follow-up interviews were conducted. The excerpt below illustrates a dialogue between the teacher and student regarding their approach to solving problems involving large stair numbers.

Teacher : "Why can you answer the problem of finding the height of the stairs to 901 but can't write in general form how you got the answer?"

Student : "We know how to get the answer, sir. But it's hard to write down the symbols."

Teacher : "Then what if you were asked to find the height of the stairs to 2001, could you find the result?"

Student : "Yes, I could, sir. If you ask me to find the height of the millionth stair, I can do it."

Teacher : "How did you get the result of finding the height of the stairs to 901?"

Student : "I got this result by using the height of the first stair plus the number of times it was climbed multiplied by the difference."

Figure 11. Briefing and Discussion SAS Feedback

Student discussions revealed that although they could solve problems involving the 901st or 2001st stair, they struggled to express general rules symbolically. Interviews confirmed their reasoning was primarily concrete rather than formal.

The findings of this study align with prior research emphasizing the benefits of contextual approaches, such as ethnomathematics and real-life situations, in supporting conceptual understanding (Dewi et al., 2020; Zahar, 2021; Lestariningsih, 2018). However, unlike cultural or everyday-life contexts, the stair context offers a structured, universally familiar, and visually straightforward representation that corresponds directly to the additive nature of arithmetic sequences. This characteristic minimizes potential cognitive overload and helps bridge the gap between concrete reasoning and formal notation. Therefore, this study contributes to PMRI-based research by demonstrating how a simple, real-life context can effectively support students in transitioning from contextual understanding to symbolic representation.

3. Retrospective Analysis

a. Analize Data

Learning process data was collected through observation, recording, and analysis of the Student Activity Sheet (SAS). The outcomes of the data analysis are presented in Table 2.

Table 2. Analysis Result

Activity	Analysis Result
Activity 1 (Observing the Stair)	Students are able to understand the initial pattern based on the observation of the stair picture. However, repetitive questions were not needed and revised for efficiency.
Activity 2 (Recording Stair Heights and Recognizing Patterns)	This activity effectively helps students recognize the arithmetic pattern as well as the fixed difference between the stairs. Students' answers are in line with the learning objectives.

Activity 3 (Identifying the Constant Difference)	Most students had difficulty in formulating a general formula, especially in using symbols such as n. They were more comfortable using concrete terms. They were more comfortable using concrete terms.
Activity 4 (Developing a General Formula Using Simplified Language)	Although students can calculate the height of the stairs with a fixed pattern, the ability to write the formula in symbol form is still a major obstacle.
Activity 5 (Applying the Pattern to Large Numbers)	Students can successfully calculate the height of a large number of stairs, such as the 901st or 2001st stairs, through logical reasoning. However, their results are conveyed verbally without using formal symbols.

b. Comparing HLT and ALT

Table 3. Comparing HLT and ALT

ALT	HLT
Students made successful observations, but the repetition of questions in the SAS reduced efficiency.	Students are expected to be able to observe and recognize the pattern of the stairs picture.
The conjecture is appropriate, students recognize the pattern and calculate the difference well. However, the symbol “b” as the difference is removed to simplify understanding.	Students are expected to record the height of the stairs and understand the difference pattern.
Most students find it difficult to formalize patterns into common symbols, so a simple approach is more acceptable.	Students are expected to be able to formulate a general stair height formula.
Students still rely on one-by-one addition and have problems expressing the method in the form of formal symbols.	Students are expected to be able to use the general formula.
Students understand and are able to calculate the result, but still have difficulty writing the method in symbolic form.	Students are expected to apply the pattern to cases with a large number of stairs.

c. Reflection and Revision

Based on the comparison between the Hypothetical Learning Trajectory (HLT) and the Actual Learning Trajectory (ALT), several key reflections and revisions were made to enhance the effectiveness of the learning design. While the overall sequence of activities aligned with the initial conjectures, some issues emerged during implementation. First, redundant questions in the SAS reduced efficiency and were therefore removed to maintain students' focus. Second, abstract symbols such as n, Un, and b caused confusion and were eliminated. Third, an observation-based introductory activity was added to help students connect the real context with mathematical representations. To address difficulties in symbolic generalization, guiding questions were introduced to scaffold students' reasoning from concrete patterns toward formal notation. These revisions were intended to provide gradual support and avoid cognitive overload. Overall, the adjustments aimed to create a more coherent and student-centered learning trajectory. Although students successfully understood the concept of arithmetic sequences through contextual activities, their symbolic reasoning required additional reinforcement. This reflection emphasizes the need for explicit strategies to bridge the gap between concrete understanding and abstract representation in future learning designs.

CONCLUSION

This study developed an arithmetic sequence learning design based on the PMRI approach using a stair context to enhance students' conceptual understanding. Implemented through three phases of design research—preliminary design, design experiment, and retrospective analysis—the study demonstrated that the stair context effectively supported students in identifying patterns and understanding arithmetic sequences concretely. However, students encountered challenges in expressing general formulas symbolically despite being able to compute values logically. Revisions, including simplifying symbols, reducing redundant questions, and introducing stepwise scaffolding, improved the learning design and facilitated connections between concrete patterns and formal notation. These findings suggest that PMRI-based contextual designs can strengthen conceptual understanding but require additional strategies to develop symbolic reasoning. Future research should explore extended interventions or alternative scaffolding techniques to bridge the gap between concrete reasoning and abstract representation.

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