Integrating Realistic Mathematics Education Approach into Instructional Websites to Improve Students' Computational Thinking Skills in Mathematics

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Abstract: Many studies have tried to improve students' computational thinking (CT) skills in mathematics learning. However, there are still gaps in improving students' CT skills, especially in integrating the realistic mathematics education (RME) approach into instructional websites. To overcome this gap, this study aims to analyze the effectiveness of applying RME-integrated instructional websites (RME-Web) in improving students' CT skills in mathematics learning. To address the study's purpose, the researchers compared the RME-Web approach with the RME and direct-learning (DL) approaches. The research method is a quantitative quasi-experimental design with a non-equivalent control group, involving up to 90 junior high school students. The data analysis techniques used are the One-Way ANOVA, Tukey HSD, and N-Gain score. The research results show that the RME-Web approach improves students' CT skills more effectively than the other two approaches. The research findings are expected to be useful for practitioners, stakeholders, and academics in designing and implementing innovative learning approaches that integrate technology and contextual pedagogy to improve students' computational thinking skills in mathematics.

Keywords: realistic mathematics education, instructional websites, computational thinking, mathematics, ANOVA

INTRODUCTION

In the 21st century, education is increasingly focused on developing students' higher-order thinking skills, including computational thinking (CT). The term CT first appeared in the context of *LOGO* programming developed by Seymour Papert in the 1980s (Papert, 1980). This idea was later developed and expanded by Jeannette Wing in 2006, who emphasized that CT is not only a technical skill limited to computer science but also a way of thinking that can be applied in various disciplines, including mathematics (Wing, 2008, 2011). These skills include data collection, data

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analysis, data representation, decomposition, abstraction, algorithms, automation, parallelization, and simulation. However, many studies show that students' CT skills are still low (Angraini et al., 2024; Ersozlu et al., 2023; Valovičová et al., 2020). Based on previous research, students' low CT skills are caused by several primary factors, such as a lack of exploratory and problem-solving-based learning, a lack of use of media or technology, and limitations in designing learning contextual and related to students' real lives. Therefore, one approach that can be used to overcome this problem is realistic mathematics education (RME). In RME, mathematical concepts are constructed by exploring real-world situations that are meaningful to students. This approach emphasizes the process of horizontal and vertical mathematization, where students first translate contextual problems into mathematical models before developing a more abstract understanding.

Furthermore, to support technological developments in the 21st century, RME can be integrated through various mathematics learning media to increase student engagement, clarify concepts, and support the mathematization process (Lisnani et al., 2023; Nurlisna et al., 2020). Various studies show that integrating RME into learning technology can help students improve their CT skills (Abdul Hanid et al., 2022; Abdullah et al., 2019; Andriyani, 2023; Payadnya et al., 2023; Triswidrananta et al., 2024; Zafrullah et al., 2023). However, does the same apply to RME integration into instructional websites? To address this question, the present study compares three groups: (1) students learning through instructional websites integrated with RME (RME-Web group), (2) students learning through face-to-face RME instruction (RME group), and (3) students learning through direct instruction without contextual exploration or technology integration (DL group). Therefore, this study aims to analyze the effectiveness of these approaches in improving students' CT skills in mathematics learning.

LITERATURE REVIEW

Computational Thinking (CT) in Mathematics

CT is a cognitive process that employs strategies to define a problem and devise its solution in a way that enables the solution to be executed effectively by information-processing agents (Wing, 2011). In addition, Yadav et al. (2014) define CT as cognitive thinking that focuses on abstracting problems and developing solutions that can be automated and computationally executed to address problems effectively. Based on these two definitions, a common thread can be drawn that CT is an analytical and systematic thinking ability that involves formulating solutions that can be implemented effectively to solve problems. According to Weintrop et al. (2016), Angeli et al. (2016), Barr & Stephenson (2011), Lee et al. (2011), and Selby (2013) state that CT includes four main indicators, as presented in Table 1. When students can understand and apply these four components of CT, they can improve their skills in solving mathematical problems effectively and

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efficiently (Cansu & Cansu, 2019; Rodríguez del Rey et al., 2021). In the context of mathematics education, CT is very important because it helps students to see mathematics not only as a series of procedures to find the right answer but as a problem-solving process that involves various steps of critical thinking (Büscher, 2024; Li et al., 2020; Ye et al., 2023). In this sense, problem-solving methodologies aim to develop students' thinking skills to gain a deeper understanding of mathematics and realize its relevance in everyday life.

CT Aspects	Description
Decomposition	Breaking a problem into parts
Pattern Recognition	Analyze data and look for patterns to gain an understanding of the data
Abstraction	Remove unnecessary details and focus on what is important
Algorithm	Create a series of sequential steps to take to solve the problem

Table 1: Computational Thinking Skill Indicators

Realistic Mathematics Education (RME)

RME is an approach that views mathematics as a human activity and must be associated with reality (Gravemeijer, 1994). On the other hand, Wijaya (2012) defines RME as a mathematical learning approach that emphasizes contextual problems as a starting point for learning, where students are invited to discover and build mathematical concepts through exploration and interaction. Based on these two definitions, a common thread can be drawn that RME is a mathematical learning approach oriented to the connection between mathematical concepts and real situations. However, it is essential to understand that the word "realistic" in RME does not necessarily mean the real world but rather a situation that students can imagine and relate to in their experiences (van den Heuvel-Panhuizen, 2001; van den Heuvel-Panhuizen & Drijvers, 2014). According to Wijaya (2012), the meaning of mathematical concepts is the main concept of RME. The concept's meaning will occur when mathematics is presented based on the student's experience (Van Oers, 1998). Therefore, mathematical concepts should be taught gradually, starting from an informal understanding and moving on to the formal aspect. RME provides a framework that helps students understand and apply mathematics more contextually. Based on this, Treffers (2012) formulated five characteristics of RME, namely: (1) The use of context, (2) The use of emergence models, (3) Student contribution, (4) Interactivity, and (5) Intertwinement. Based on these five characteristics, according to Wijaya (2012) realistic contexts or problems are used as a basis for developing mathematical concepts or as a source for learning.

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Instructional Websites in Mathematics Education

An instructional website is a digital platform designed to support learning by providing materials, interactive activities, and evaluations in a structured environment (Harsanto, 2017). In the context of mathematics learning, instructional websites have great potential to accommodate various student needs, including facilitating conceptual understanding through visual media, simulations, and contextual problems (Borba et al., 2016; Nyoto Kurniawan, 2013). The platform allows for flexible learning, where students can access the material at any time and from anywhere and engage in a more personalized and immersive learning experience (Cacheiro-Gonzalez et al., 2019). In addition, the platform can be designed to integrate learning approaches such as RME, which emphasizes the use of contextual problems to build student understanding. Various studies have shown that instructional websites have a positive impact on students' mathematical thinking skills (Buchori et al., 2023; Istiqomarie & Mulyono, 2023; Lisnani et al., 2023; Sosa et al., 2023).

Research Gaps and Novelty

Several previous studies have attempted to improve students' CT skills through the integration of RME into instructional technology, such as augmented-reality (Abdul Hanid et al., 2022), mobile applications (Abdullah et al., 2019), android media (Zafrullah et al., 2023), virtual-reality (Payadnya et al., 2023), and educational games (Andriyani, 2023; Triswidrananta et al., 2024). However, research gaps exist in integrating RME into instructional websites to improve students' CT skills in mathematics learning. Therefore, this study offers novelty in analyzing the effectiveness of RME-integrated instructional websites (RME-Web) in improving students' CT skills. Practitioners, stakeholders, and academics can utilize the significance of this research. Practitioners can utilize real-life context-based learning approaches and technology to improve students' CT skills. At the same time, stakeholders and academics can use these results as a reference in teacher training, curriculum development, and literature on innovative mathematics learning approaches.

METHOD

Research Design

The research method used is a quantitative quasi-experimental type of non-equivalent control group design, comparing three sample groups representing three learning approaches: (1) RME-integrated instructional websites (RME-Web) approach as the experimental group 1; (2) the RME

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approach as the experimental group 2, and (3) the direct-learning (DL) approach as the control group. The research design can be seen in Table 2.

Samples Groups	Pretest	Treatment	Posttest
Experimental 1	O_1	T_1	O_2
Experimental 2	O_3	T_2	O_4
Control	O_5	X	O_6

Table 2: Research Design

Table 2 shows the research design where O_1, O_3, and O_5 represent the pretest for the experiment group 1, experimental 2, and control. Meanwhile, O_2, O_4, and O_6 represent the posttest in the same group. Based on the treatment column, T_1 represents the treatment for experimental group 1 using the RME-Web approach, T_2 represents the treatment for experimental 2 using the RME approach, and X represents the control group using the DL approach.

Participants

This research was carried out in one of the private junior high schools in Yogyakarta, Indonesia, in September-October 2024. The population is all grade VIII students (ages 13-15 years), with as many as eight classes and 209 students. Three classes were randomly selected, and a sample of class VIII G was obtained, with 30 students as experimental group 1, class VIII H with 30 students as experimental group 2, and class VIII F with 30 students as the control group. The selection of schools is based on the availability of internet access and the overall readiness of students to engage in web-based learning media. The students have expressed their willingness to participate voluntarily. All treatment of students is carried out ethically following the guidelines set by the American Psychological Association (American Psychological Association, 1992)

Instruments

The researchers used a data collection technique in the form of a cognitive test on the topic of number patterns. The type of test is a description consisting of five questions. Each question item represents every CT skill. The grid of question items can be seen in Table 3. Pretest and posttest questions are identical to accurately compare students' skills before and after the learning intervention. The test duration of 120 minutes provides enough time for students to read, understand, and solve problems carefully. The total score in the assessment is 100 points, giving

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equal weight to each question, which is 20 points, which are scored based on completeness, accuracy, and clarity of the answers.

Computational Thinking Indicators	Description	Question Items
Decomposition	Students should break down the beats by instrument and analyze where the beats occur and overlap.	(1)
Pattern recognition	▪ Students identify consistent patterns in the packing process (number of pieces per bundle and bundles per basket).	(2)
	▪ Students identify recurring geometric patterns in Batik motifs and how they develop at each level of enlargement.	(5)
Abstraction	Students generalize the ticket price increase pattern and formulate it as a mathematical model	(3)
Algorithm	Students design a step-by-step algorithm to calculate the number of visitors on day 10 based on a growth pattern.	(4)

Table 3: Question Instrument Grid

Data Analysis Techniques

After the test instrument is completed, the next stage is the internal validity test. Internal validity involves the validation of material by three validators using the Likert Scale of four categories: "1" (strongly disagree), "2" (disagree), "3" (agree), and "4" (strongly agree). The validation instrument was analyzed using the content validity ratio (CVR) formula, namely Cohen's Kappa inter-raters (McHugh, 2012), with a score of "0.87", which indicates the level of reliability between strong validators (strong agreement). The validity of the content of each question was tested using the content validity index (CVI) formula, namely Aiken's Coefficient Value (Aiken, 1985), which resulted in a score of "0.88" (question number 1), "0.90" (question number 2), "0.92" (question number 3), "0.94" (question number 4), and "0.96" (question number 5), indicating high validity (very valid) for each question item. Furthermore, a pilot study was conducted to assess the instrument's readability, involving six students with low, medium, and high abilities. The results of the pilot study showed a number error in question 2, which prevented the answer from being searched, as well as difficulty understanding question 3, especially for students with low and medium ability. Based on these findings, revisions were made to improve the instrument's clarity and accuracy. This process ensured that the instrument was both theoretically valid and practically applicable, reducing potential measurement bias.

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After the instrument was declared valid, large-scale data was collected, and the results of the pretest-posttest were tested for normality and homogeneity using RStudio software version 4.3.2 (RStudio Team, 2023) with packages "dplyr" as the assumption of normality (Wickham et al., 2023), "car" as the assumption of homogeneity (Fox & Weisberg, 2019), and "lsr" to determine the eta-squared (Navarro, 2015) with $\alpha = 5\%$. The normality assumption hypothesis is H_0: Normally distributed data and H_1: Data is not distributed normally. Assumption of normality using statistics of the Shapiro-Wilk test where H_0 was rejected if p-value < α. Furthermore, the hypothesis of the homogeneity assumption of variance is H_0: The homogeneity of the variance is the same, and H_1: There is at least a pair of heterogeneous variances that are not the same. Homogeneity assumptions using Levene test statistics where H_0 was rejected if p-value < α. This is in line with Zimmerman & Zumbo (1992) where the criteria for normally distributed data meet the level of homogeneity of variance if the p-value > 0.05.

Furthermore, after confirming that the data is normally distributed and the variance is homogeneous, the data can be analyzed parametrically using the One-Way ANOVA test to see whether there are significant differences in students' average CT skill scores from the three sample groups. If the results of the One-Way ANOVA test are significant, a post hoc test is carried out using the Tukey HSD test introduced by Tukey (1953) to see which approach is better for improving students' CT skills during mathematics learning. Furthermore, to determine the magnitude of the influence of the intervention of the three approaches on the average CT skill score, the effect size formula of the eta-squared was used (η^2). It should be noted that the effect size criteria are based on Abbott (2014) with categories of "0.01" (small), "0.06" (medium), and "0.15" (large). In addition, the N-Gain score is used to measure the effectiveness of implementing each intervention approach. The N-Gain model used is an average of the N-Gain score because the researchers have student response data that can be analyzed directly. The interpretation of the N-Gain score is based on Hake (1999) with the categories: "<40%" (ineffective), "40-55%" (less effective), "56-75%" (quite effective), and ">76%" (effective).

Research Procedure

This study used three sample groups: experimental group 1 with the RME-Web approach, experimental group 2 with the RME approach without learning technology, and the control group with the DL approach. The topic used in this study is number patterns. The RME approach used by the researchers has several syntaxes, namely: (1) Contextual Problem, (2) Contextual Exploration, (3) Concept Exploration, (4) Mathematization, (5) Generalization, and (6) Reflection and Evaluation. The learning syntax of RME-Web can be seen in Figure 5, while RME is in Figure 6. In the RME-Web group, the principles of RME were embedded into the instructional website,

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where contextual problems, exploration, mathematization, and reflection were facilitated through interactive simulations, automated feedback, and online discussions. In the RME group, the same syntaxes were applied in a face-to-face classroom setting, where students engaged directly in contextual exploration and discussions guided by the teacher. In contrast, the DL group followed a conventional teacher-centered approach, focusing on the direct delivery of mathematical concepts and procedures without contextual exploration or technology integration.

To implement the learning activities, both experimental groups engaged in projects based on real-life and cultural contexts related to number patterns. In the RME-Web group, projects such as analyzing the rhythmic structure of *Gending Lancaran*, exploring the folding patterns of *Wiru Jarik*, and identifying Batik motif repetitions were transformed into interactive website content. In the RME group, the same projects were carried out through hands-on activities such as arranging classroom chairs, folding paper, or discussing Batik motifs directly with peers under the teacher's guidance.

Contextual Problem Stage

Experimental group 1 implemented the RME-Web approach, incorporating instructional websites featuring interactive simulations, visualizations, and step-by-step guidance. This group used local cultural contexts from Yogyakarta, Indonesia, such as *Gending Lancaran* (a traditional Javanese song scale) and the *Wiru Jarik* tradition (folding Batik cloth). The research procedure begins with the "contextual problem" stage, where students are given contextual problems related to the number patterns. Experimental group 1 with the RME-Web approach uses the local cultural context of Yogyakarta, where students were presented with digital problems that contextualized number patterns using visual depictions of *Gending Lancaran* scales or animated representations of the *Wiru Jarik* folding process. These problems were carefully designed to align with the RME principles of connecting mathematics to real-world and cultural phenomena. This stage is categorized as an informal or experience-based phase, where students explore problems related to their surroundings, specifically their cultural environment. By engaging with cultural practices such as the *Gending Lancaran* and *Wiru Jarik* traditions, students are encouraged to discover and understand number patterns through their own cultural experiences. Meanwhile, experimental group 2 with the RME approach without learning technology used the context of chairs in the classroom and folding paper, where students were given contextual problems related to number patterns through physical and manipulative activities. In this context, students are asked to arrange chairs in the classroom following a particular pattern or fold the paper in different shapes to understand the number of patterns formed. The control group applied the DL approach, where the

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teacher provided direct explanations without incorporating cultural context or learning technology. This approach introduced students to number patterns through traditional textbook problems.

Contextual Exploration Stage

In the "contextual exploration" stage, experimental group 1 explored the problem using available media or tools. By interacting with simulations depicting the *Gending Lancaran* scale and visualizing the folding process of Batik cloth, students could see real-time changes and patterns, providing immediate feedback on their exploration. For example, see Figure 1, in the notation of the song "*Gugur Gunung*", it can be observed that each time signature (*gatra*) consists of four notes. Thus, in each stanza, there are 16 notes. Generally, a song has a minimum of five stanzas, so the total tone in this song reaches 80 notes. Experimental group 2 explored patterns by manually arranging class seats or folding paper to understand the patterns (see Figure 2). For instance, students would arrange chairs in rows to form a visible pattern and explore how the number of chairs changed based on a particular rule. Similarly, by folding paper, students could see physical transformations mirrored the number patterns concept. This exploration allowed for an experiential learning process where students could apply their observations to formulate hypotheses and test their ideas. The control group only received explanations of the material topic from the teacher without in-depth exploration or special aids. Students worked through practice problems provided by the teacher, focusing on basic problem-solving techniques without any contextual or interactive support.

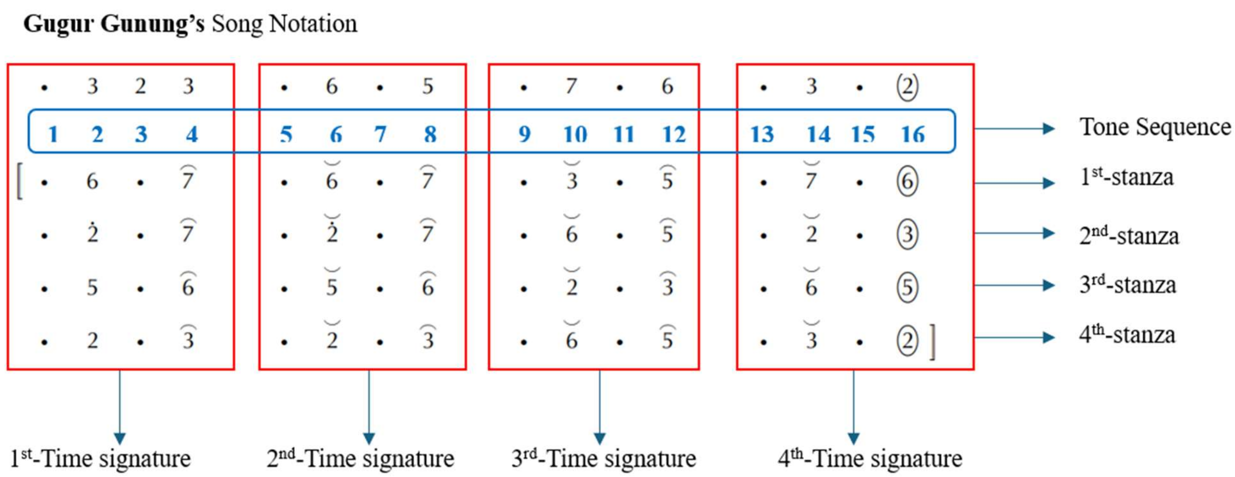

Figure 1: Contextual Exploration in *Gugur Gunung's* Song Notation

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Figure 2: Contextual Exploration Process in Paper Folding

Concept Formulation Stage

The "concept formulation" stage involves students formulating the concept of number patterns based on their exploration results. In experimental group 1, students identified the mathematical structure underlying the cultural activities through guided prompts on the website. The website provided feedback mechanisms that allowed students to refine their understanding based on their responses, helping them link the cultural context with mathematical concepts. In addition, students engaged in online discussions through the platform, where they could share responses, comment on peers' ideas, and collaboratively refine their reasoning under the teacher's moderation. To illustrate, the notes in Figure 1 are played on the *Kethuk*, which serves as a rhythm guard in the musical composition. The notation generated by this tool, as shown in Figure 3, forms a pattern of odd numbers in constant increments. In experimental group 2, students used physical aids or engaged in group discussions, with the teacher guiding them to analyze their explorations and formulate mathematical concepts collaboratively. For example, in Figure 4, the process of folding paper produces a certain number pattern. Each paper is folded, the number of parts formed doubles from before. In contrast, the control group was directly instructed by the teacher, who explained the concept of number patterns without involving any contextual exploration or interactive feedback.

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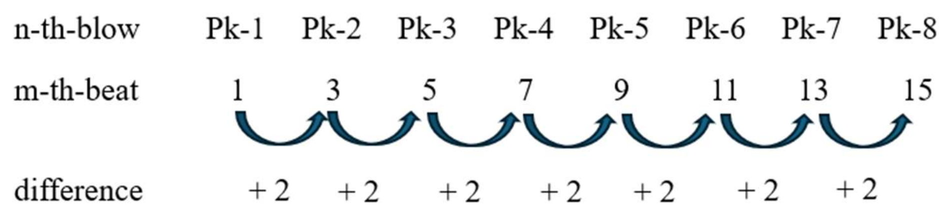

Figure 3: Concept Formulation in *Kethuk's* Beat Notation

Number of paper folding	**1 time**	**2 times**	**3 times**	**4 times**
The number of equal parts formed	2 parts	4 parts	8 parts	16 parts

Figure 4: Concept Formulation in Paper Folding

Mathematization Stage

The "mathematization" stage, students are tasked with transforming the identified patterns into mathematical models. In experimental group 1, students used the instructional website to convert cultural contexts into mathematical representations. For example, when studying the *Gending Lancaran* scale, students identified the numerical intervals between notes as part of a pattern and expressed these intervals as a series of numbers. In the case of the *Wiru Jarik* folding process, students recognized a step-by-step sequence and mapped it to a numerical pattern, such as counting the number of folds or measuring the length of fabric after each fold. The website's tools helped students visualize and input these patterns into mathematical formulas, such as identifying arithmetic progressions or simple number patterns. In experimental group 2, students manually arranged chairs or folded paper to create patterns. For instance, when arranging chairs, students noted the sequence of chair numbers in rows, identifying a progression, such as increasing by one or two chairs per row. They then translated these arrangements into mathematical notation, such as writing a formula to represent the relationship between the number of chairs and the row number. Similarly, while folding paper, they recognized repeated patterns in the number of folds and expressed this as a number pattern. In the control group, students worked with textbook problems where they were asked to identify patterns in a list of numbers or shapes. The teacher provided instructions on recognizing number patterns, such as identifying whether a pattern was increasing or decreasing. However, students did not engage in any contextual or hands-on learning.

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Generalization Stage

In the "generalization" stage, students applied their understanding of number patterns to new, more complex problems. In experimental group 1, students used additional simulations and mathematical problems provided on the instructional websites. They extended the mathematical concepts they had learned, such as creating new sequences and predicting future terms based on the number of patterns identified in cultural contexts. In experimental group 2, students used manual tools like classroom objects and paper folding to explore more complex problems, applying their previously identified patterns. The control group worked with teacher-provided textbook problems, focusing on mathematical tasks without the contextual or interactive elements.

Reflection and Evaluation Stage

All groups reflected on their learning in the "reflection and evaluation" stage. Experimental group 1 received instant feedback through the website’s automatic evaluation feature, allowing students to quickly assess their understanding and refine their approaches. The teacher also provided feedback both online, through discussion forums on the platform, and offline, during follow-up sessions, to guide students in evaluating their reasoning and conceptual understanding. Experimental group 2 and the control group were reflected through class discussions, during which the teacher provided feedback. However, the feedback in the control group was limited to general comments, while in experimental group 2, the feedback was more focused on students’ manual problem-solving processes.

This study used pretest and posttest before and after treatment to measure students' CT skills. The test includes CT skill indicators, namely decomposition, pattern recognition, abstraction, and algorithms, which are tailored to the topic of the number patterns. The pretest was conducted to measure the students' initial ability, while the posttest aimed to evaluate the improvement of CT skills after treatment in the form of a learning approach.

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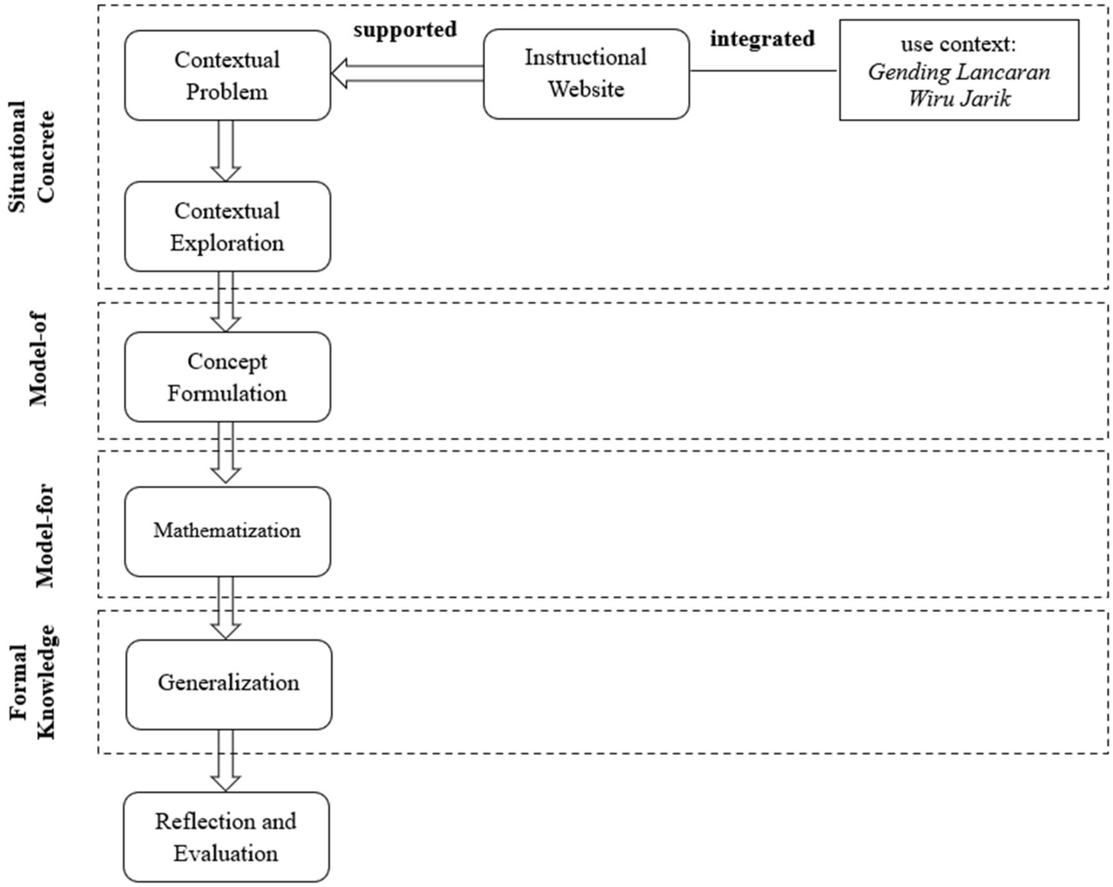

Figure 5: RME-Web syntax

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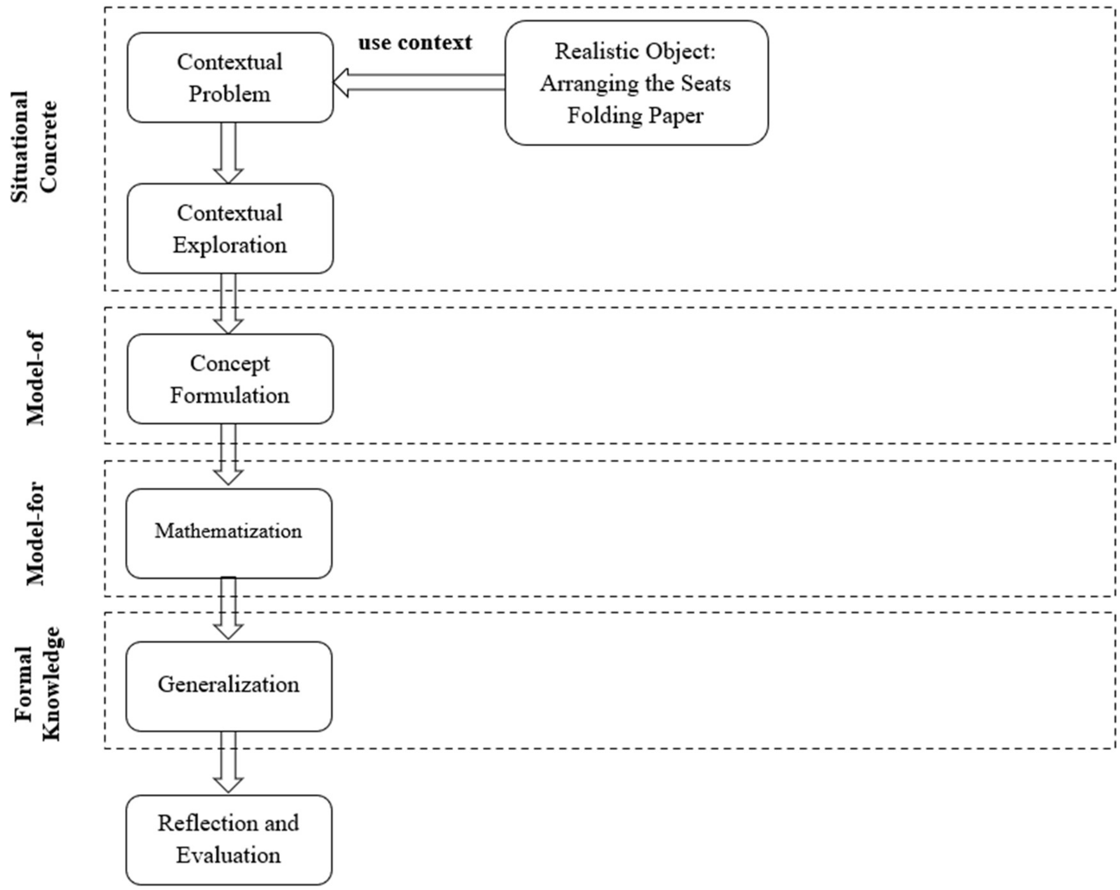

Figure 6: RME Syntax

Research Hypothesis

Several previous studies have tried to integrate RME into instructional media to improve critical thinking skills (Wijayanti et al., 2022) and problem-solving (Sukmaningthias et al., 2023). In addition, several previous studies have also used instructional websites to improve students' CT skills (Bers, 2018; Latifah et al., 2023). Based on this, researchers can hypothesize that integrating RME into instructional websites can improve students' CT skills. The hypothesis can be formulated as follows:

H_1: There was a significant difference in the average CT skill scores of the three sample groups

H_2: Experimental group 1 had a higher average CT skill score than experimental 2

H_3: Experimental group 1 had a higher average CT skill score than the control

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RESULT

This section describes the results of the analysis of two data groups, namely the analysis of initial ability and final ability after treatment. The data collection process is offline, starting from pretest data, treatment provision, and posttest data.

Results of Pretest Data Analysis

Before providing treatment, the researchers conducted a balance test on the initial ability data to find out whether the student population who received the RME-Web treatment approach (experimental 1), RME (experimental 2), and DL (control) had the same initial ability. Before the balance test, a prerequisite test is carried out, namely a normality assumption test and variance homogeneity. The normality assumption test was carried out on each sample group. The normality assumption test in the three groups used the Shapiro-Wilk formula, as presented in Table 4.

Sample Groups	Variable Statistic	p-value
RME-Web	Pretest	0.121
RME	Pretest	0.118
DL	Pretest	0.486

Table 4: Results of Pretest Data Normality Test Analysis

After the normality test assumption analysis, a group of data can be said to be normally distributed if the p-value > 0.05. Table 4 shows that the p-value of each group > 0.05 (H_0 was not rejected). This means the data in the groups with the RME-Web, RME, and DL approaches is normally distributed.

Levene Statistic	df1	df2	p-value
0.389	2	87	0.679

Table 5: Results of Pretest Data Variance Homogeneity Test Analysis

After a variance homogeneity assumption test was carried out using the Levene formula, the three sample groups were said to have homogeneous data variance if the p-value > 0.05. Table 5 shows that the p-value is at 0.679 > 0.05. These results indicate that the three groups have homogeneous variances (H_0 is not rejected). Thus, the process of analyzing pretest data can be continued to the next stage, namely the One-Way ANOVA test, to see if the average score of the student's CT skills from the three groups before treatment has a significant difference. Meanwhile, according to Kim (2017), a significant difference can be identified if the p-value of the One-Way ANOVA test is below 0.05. Table 6 shows that the p-value is at 0.718 or above 0.05. This means H_0 was not

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rejected. There was no significant difference in students' average CT skills scores from the three sample groups.

This is strengthened by the descriptive analysis test in Table 7, where the average scores of the three sample groups do not show a sharp and significant difference. This shows that the three sample groups have a balanced initial understanding to continue to provide treatment, as described in Table 2.

Condition	df	Sum of Squares	Mean Square	F	p-value
Model	2	107	53.39	0.332	0.718
Residuals	91	14630	160.77		

Table 6: Results of Pretest Data of One-Way ANOVA Test Analysis

Sample Groups	Mean	Minimum	Maximum	Std. Deviation
RME-Web	55.74	30.00	76.00	12.78
RME	57.19	36.00	92.00	13.34
DL	56.59	32.00	80.00	11.90

Table 7: Results of Pretest Data of Descriptive Test Analysis

Results of Posttest Data Analysis

After the three sample groups were given learning treatment as stated in the research design (see Table 2), the researchers gave a posttest to the students. This posttest aims to determine whether there is a significant difference in the average student's CT skill score between the RME-Web, RME, or DL groups. Therefore, the students' work results were first tested for statistical prerequisites, namely the normality assumption test using the Shapiro-Wilk formula and the homogeneity of variance with the Levene formula. The analysis results can be seen in Table 8 and Table 9.

Sample Groups	Variable Statistic	p-value
RME-Web	Posttest	0.141
RME	Posttest	0.081
DL	Posttest	0.139

Table 8: Results of Posttest Data Normality Test Analysis

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Table 8 shows that the p-values of the three groups are above 0.05 (H_0 was not rejected). This means that the data in all three groups are normally distributed. Furthermore, Table 9 shows the p-value at 0.755 (H_0 was not rejected). This means that all three groups are categorized as homogeneous.

Levene Statistic	df1	df2	p-value
0.281	2	87	0.755

Table 9: Results of Posttest Data Variance Homogeneity Test Analysis

After confirming that the posttest data was normally distributed and homogeneous, the One-Way ANOVA test was continued to determine if there was a significant difference in the average score of students' CT skills from the three sample groups. Table 10 shows the analysis results of the One-Way ANOVA test with a significance value of p-value = 0.000 < 0.05 (H_0 was rejected), meaning a significant difference in the average students' CT skills score from the three sample groups.

Condition	df	Sum of Squares	Mean Square	F	p-value
Model	2	2697	1348.3	54.63	0.000
Residuals	87	2147	24.7		

Table 10: Results of Posttest Data of One-Way ANOVA Test Analysis

Furthermore, to find out how much the difference in learning approach interventions affects students' CT skills, the effect size can be used, namely eta-squared (η^2). The result was η^2= 0.5567, meaning that 55.67% of the variance in students' CT skills was obtained from the difference in the three interventions of the learning approach (RME-Web, RME, and DL). This effect size value is relatively large.

Furthermore, a post hoc test analysis was carried out using the Tukey HSD formula to determine which approach is better for improving students' CT skills. Based on the 95% confidence interval containing 0 and the p-value < 0.05 contained in Table 11, it shows that the application of the RME-Web approach significantly influences students' CT skills compared to the RME approach. Furthermore, the RME-Web approach also has significant differences compared to the application of the DL approach. This result is confirmed by the analysis of the descriptive test in Table 12, where the group with the RME-Web approach has a higher average score than the other two approaches.

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Sample Groups		Mean Dif.	Lower	Upper	p-value	Meaning
RME-Web	RME	3.16	0.11	6.22	0.041	Significant
	DL	12.86	9.81	15.93	0.000	Significant
RME	RME-Web	-3.16	-6.22	-0.11	0.041	Significant
	DL	9.70	6.64	12.76	0.000	Significant
DL	RME-Web	-12.86	-15.93	-9.81	0.000	Significant
	RME	-9.70	-12.76	-6.64	0.000	Significant

Table 11: Results of Posttest Data of Tukey HSD Test Analysis

Sample Groups	Mean	Minimum	Maximum	Std. Deviation
RME-Web	83.53	74.00	92.00	4.86
RME	80.37	72.00	88.00	6.66
DL	70.67	58.00	80.00	5.36

Table 12: Results of Posttest Data of Descriptive Test Analysis

Finally, the average type of the N-Gain score can be used to determine the effectiveness of each intervention approach. Based on the results of the analysis in Table 13, the RME-Web approach is included in the category of quite effective, the RME approach is in the category of less effective, and the DL approach is in the category of ineffective. Therefore, it can be concluded that the RME-Web approach is more effective in improving students' CT skills than the RME and DL approaches.

Learning Approach	Average of N-Gain Score
RME-Web	63.61%
RME	54.19%
DL	32.43%

Table 13: Results of N-Gain Score

DISCUSSION

The big idea of this study is to analyze the effectiveness of integrating the RME approach into instructional websites (RME-Web) in improving students' CT skills in mathematics learning. To see the level of effectiveness, the researchers compared the application of the RME-Web approach with the RME and DL approaches. As previously explained, this section discusses the three hypotheses that have been proposed. Hypothesis 1 (H_1) was to see whether there was a significant

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difference in the average students' CT skills score from the three sample groups tested. Based on Table 10, it can be seen that the p-value < 0.05, which is at 0.000. So, the decision that can be taken is to reject H_0 or accept H_1. This means that there is a significant difference in the average CT skill scores of students in the three sample groups.

Furthermore, Hypothesis 2 (H_2) was used to test whether experimental group 1 had a higher average CT skill score than experimental 2. Based on Table 11, comparing the average CT skill score of students in the RME-Web approach and RME in the Mean Difference column of the first row obtained an average score of 3.16, which is positive. Therefore, based on the 95% confidence interval containing 0 and p-value < 0.05, it can be concluded that there is a significant difference in the average score of the two learning approaches, with the average score of the RME-Web approach higher than that of the RME (H_0 was rejected). In other words, the RME-Web approach improves students' CT skills better than RME.

Hypothesis 3 (H_3) was used to test whether experimental group 1 had a higher average CT skill score than the control. Based on Table 11, comparing the average CT skill scores of students in the RME-Web and DL approaches in the second row of the Mean Difference column obtained an average score of 12.86, which is positive. Therefore, based on the 95% confidence interval containing 0 and a p-value < 0.05, it can be concluded that there is a significant difference in the average score of the two learning approaches, with the average score of the RME-Web approach higher than that of DL (H_0 was rejected). In other words, the RME-Web approach improves students' CT skills better than DL.

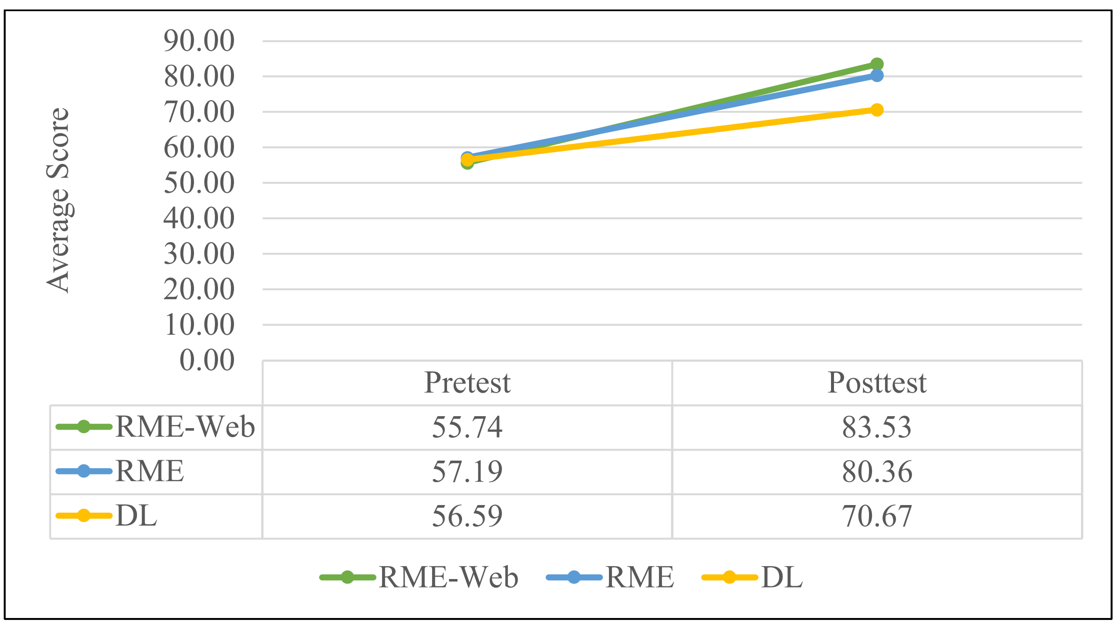

Figure 7: Graph of Average Increase in Student's CT Skill Score

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Based on the results of the three hypothesis tests, it can be concluded that the average CT skill score of students in experimental group 1 is higher than that of the other two sample groups. This was also clarified by the increase in the average pretest-to-posttest scores from the three sample groups. Figure 7 shows an escalation graph of students' average CT skill scores from the three sample groups. It can be seen that the average score of the group with the RME-Web approach (red line) has the most significant improvement compared to the group with RME (purple line) and DL (light blue line). The results of the N-Gain score analysis further reinforce these findings, with the RME-Web approach being included in the "quite effective" category. This means that this approach is not only effective in improving students' CT skills but also contributes significantly to the achievement of better learning outcomes compared to the RME approach, which is only based on a contextual approach without technology integration, as well as the DL approach, which is more teacher-centered.

The findings of this study are important because they confirm the success of using websites as a learning medium that can enrich students' learning experiences in learning mathematics in the 21st century. This is also confirmed by previous research, which shows that instructional websites can improve the quality of mathematics learning (Buchori et al., 2023; Lisnani et al., 2023; Suripah & Susanti, 2022). The RME-Web approach combines the power of RME based on contextual problem-solving with the benefits of technology, allowing students to engage in more authentic, contextual, and meaningful learning. RME, as an approach emphasizing real-world context-based mathematics learning, has proven effective in improving students' understanding of mathematics. This is reinforced by research conducted by Dhayanti et al. (2018); Nuraida & Amam (2019); Risdiyanti & Prahmana (2021); Umbara & Nuraeni (2019); and Payadnya et al. (2023) where the main principle of RME is to utilize relevant everyday contexts to help students understand mathematical concepts through real-life experience and problem-solving.

According to Gravemeijer (1994), RME has been recognized as an effective approach to developing students' understanding of mathematics. Furthermore, as conducted in this study, integrating technology such as instructional websites in the learning process can significantly improve the quality and outcomes of learning. In this study, the RME-Web approach expands the RME approach by integrating technology as an instructional website that provides various exercises, simulations, and exploration of context-based mathematical problems. This strengthens the principle of RME in giving context to math learning and allows students to develop indispensable CT skills in the 21st century.

The RME-Web approach significantly impacts all four aspects of CT skills. In *Gending Lancaran*, students must break down the structure of the music into smaller components, such as the sequence of beats in a specific unit of time and the relationships between notes in a single *gending* (song).

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This process trains the "decomposition" aspect because students learn to identify complex rhythmic patterns before generalizing regularity in number patterns. Meanwhile, in *Wiru Jarik*, the repetitive and consistent pattern of fabric folds reflects the mathematical principle in the number pattern. Students analyze the regularity of these folds, practicing the "pattern recognition" aspect by recognizing geometric patterns and regularity in the structure of *Wiru*. Students generalize their findings into more abstract mathematical concepts after understanding the patterns in *Gending Lancaran* and *Wiru Jarik*. In *Gending Lancaran*, they convert the beat pattern into a series of numbers that represent the duration or frequency of the beat, while in *Wiru Jarik*, they model the fold pattern as a number pattern. This process develops the skills of the "abstraction" aspect. In addition, in both *Gending Lancaran* and *Wiru Jarik*, there are specific rules in the pattern that must be followed. Students devise systematic steps to understand, reproduce, or modify patterns. For example, arrange the order of the beats in *Gending Lancaran* or determine the steps for folding the fabric in *Wiru Jarik*. This skill trains the “algorithmic thinking” aspect as students design procedures that can be tested and reapplied in various mathematical contexts. Figure 8 shows the students' answers to question number 5, which measures the pattern recognition aspect in the group that received the RME-Web approach treatment. Based on the image, it can be seen how students recognize Batik motif patterns, allowing him to determine the number of Batik motifs in a particular pattern. This process demonstrates students' skill to identify similarities and regularities in a complex pattern.

At this point, it is clear that the RME-Web approach fosters the development of CT skills by integrating cultural contexts into mathematics learning. Next, based on observations in experimental group 1, the RME-Web approach helps students reinvention number patterns through interactive simulations, digital visualizations, and automated feedback. This supports the “guided reinvention” process, where students gradually mathematize their experiences from contextual problems to abstractions. The “progressive mathematization” principle is also well facilitated because students can take advantage of technological features to learn mathematical patterns, relationships, and structures gradually. This confirms the research by Lisnani et al. (2023), and Payadnya et al. (2023), which shows that the technology in the RME approach improves guided reinvention and progressive mathematization through more independent interactions and visualizations. In contrast, the RME approach without technology in experimental group 2 still applies RME principles. However, learning relies more on group discussions and manual representation, so the scaffolding provided is limited to direct intervention from the teacher. In previous research findings, as described by Nugroho et al. (2025) and Laurens et al. (2018), group discussions and manual representations can help students build mathematical understanding collaboratively. This collaborative process, supported by the teacher’s role as facilitator, enabled students to engage in contextual exploration, share ideas, and collectively formulate mathematical

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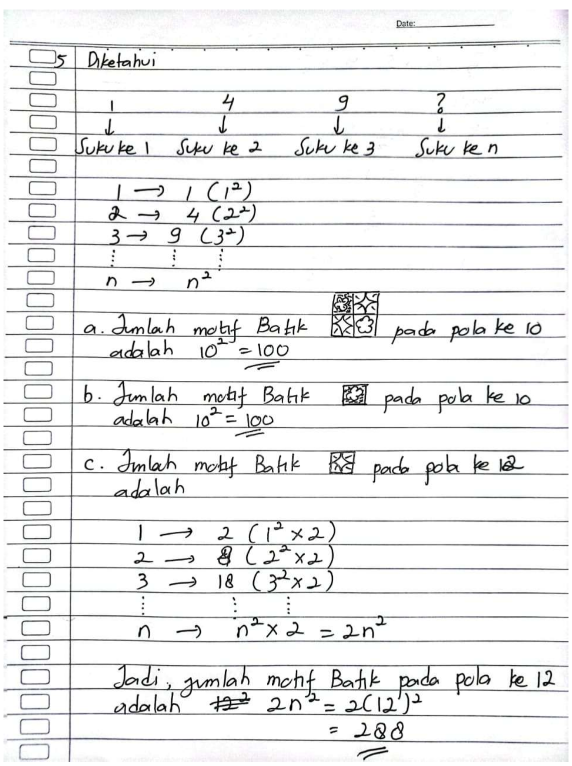
concepts. As a result, the RME group showed better outcomes than the DL group, indicating that contextual, discussion-based learning can significantly enhance students' CT skills.

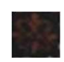
In addition, the principle of "didactical phenomenology" is seen in both experiments, where contextual problems relevant to students' lives (Yogyakarta culture) are selected to motivate them to understand mathematical concepts. However, experimental 1 showed a better increase in interactivity than experimental 2 because technology allows students to be more independent and active in the exploration process and provides a more dynamic learning experience. This is in line with research conducted by Payadnya et al. (2023) and Shahidayanti et al. (2024), where the principles of didactical phenomenology are strengthened by the use of technology that supports students' more intensive experience and reflection on mathematical phenomena. In learning in the control group, teachers directly convey mathematical concepts through lectures, demonstrations, and practice questions without much involvement in exploring contextual problems. Nugroho & Septianisha (2025) and Nugroho et al. (2024) note that a more didactic and structured teaching approach can hinder students' creative exploration in the context of mathematics learning.

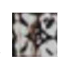


Known

1st Term 2nd Term 3rd Term nth Term

a. The number of Batik motifs  in the 10th pattern is $10^2 = 100$

b. The number of Batik motifs  in the 10th pattern is $10^2 = 100$

c. The number of Batik motifs  in the 12th pattern is ….

So, the number of Batik motifs in the 12th pattern is $2n^2 = 2(12)^2 = 288$

Figure 8: Sample Answers of Experimental Group 1 Students for Question Number 5

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In addition, the integration of local cultures in mathematics learning can increase students' engagement and understanding of the material because students feel closer to the content being taught, as revealed by previous research (Lidinillah et al., 2022; Nurmala Sari Agustina et al., 2021; Risdiyanti & Prahmana, 2021; Utari et al., 2024). This aligns with the principle of didactical phenomenology, which brings cultural phenomena closer to students as a starting point for learning mathematics (Prahmana, 2022). By connecting mathematical concepts to students' cultural contexts, learning becomes more meaningful and relevant, allowing students to see mathematics not as an abstract discipline but as a tool for understanding and interpreting the world around them. In this study, using Yogyakarta's local culture, such as *Gending Lancaran* and the *Wiru Jarik* tradition, provides a rich context of patterns and structures, making it very relevant to help students understand the concept of number patterns more meaningfully.

Meanwhile, the RME approach based on the mathematical context of everyday life without the integration of technology (such as the one used in experimental group 2) still yielded good results but was not comparable to the success achieved with RME-Web. This can be seen in the results of the Tukey HSD test in Table 11, where the p-value between RME-Web and RME is 0.041, which shows a value close to the significance limit of 0.05. This means that although the difference in students' average CT skill scores between these two groups is statistically significant, the difference in average is not very large. This is in line with research results that show that although contextual approaches such as RME can deepen student understanding, technology integration provides an additional dimension that enriches the student learning experience (Hilda & Siswanto, 2021; Lestari et al., 2023; Sukmaningthias et al., 2023; Yuliasari et al., 2021). Meanwhile, the control group that used the DL approach showed lower results in CT skills. This approach focuses more on direct and procedural instruction without much contextual exploration, so students are less involved in the critical and analytical thinking process. As a result, aspects of CT do not develop optimally. This result is in line with previous research, which stated that context-based learning is more effective in improving conceptual understanding compared to direct learning, which tends to be mechanistic (Wijaya et al., 2015, 2018). Overall, all three learning approaches significantly impacted students' CT skills. This can be seen from the relatively large effect-size value (η^2). In mathematics education, this value indicates that changes in learning approaches, such as the use of RME-Web, RME, and DL, strongly influence improving students' CT skills.

These findings open up opportunities for further research, especially in expanding the application of RME-Web to various levels of education other than junior high school, such as elementary, high school, or college. Advanced research can also explore integrating advanced technologies, such as augmented-reality (AR), virtual-reality (VR), gamification, and mobile apps to create more immersive and enjoyable learning experiences. In addition, the study focuses solely on computational thinking skills so that future research may expand the scope to other 21st-century

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skills, such as collaboration, critical thinking, problem-solving, communication, and creativity, while considering students' factors, such as motivation, interests, and learning styles, that may affect the effectiveness of learning approaches.

CONCLUSIONS

This study aims to analyze the effectiveness of the RME-integrated instructional websites (RME-Web) approach in improving students' CT skills in mathematics learning. Based on the One-Way ANOVA and Tukey HSD test analysis, the RME-Web approach has a better average score for students' CT skills than the RME and DL. These findings are supported by the results of the N-Gain score analysis, where applying the RME-Web approach is quite effective in improving students' CT skills. Therefore, it can be concluded that the RME-Web approach is more effective in improving students' CT skills than the other two approaches. The effectiveness of the RME-Web approach was supported by the integration of contextual problems, interactive simulations, cultural-based tasks, and online discussions that enabled students to explore, collaborate, and reflect more independently. These features strengthened the principles of guided reinvention and progressive mathematization, allowing students to gradually move from contextual experiences to abstract mathematical concepts. Although the difference between the RME-Web and RME groups was statistically significant, it was relatively small, suggesting that the RME group also achieved notable success. This can be attributed to the use of contextual exploration, group collaboration, and teacher facilitation, which enabled students to actively engage in problem-solving and concept-building. These elements made the RME approach more effective than the DL group, which relied primarily on direct, teacher-centered instruction.

Based on these findings, the researchers recommend that educators and curriculum designers integrate the RME-Web approach into mathematics education. For educators, this study offers an innovative technology-enhanced, culture-based learning strategy that fosters independent learning and helps students develop CT skills in local cultural contexts. Educators can implement this approach by integrating instructional websites with structured RME-based activities, fostering active engagement and deeper mathematical understanding. For curriculum designers, the RME-Web approach can serve as a framework for developing curricula, and it underscores the need to integrate digital learning modules that incorporate local traditions to ensure instructional materials are conceptually rich and relevant to students' cultural backgrounds. Additionally, teacher training programs should emphasize culturally contextualized technology integration to optimize the effectiveness of RME-Web in various educational settings. By bridging technology, culture, and contextual mathematics learning, this study provides a scalable and effective model for developing

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students' CT skills while preserving and promoting local heritage. This is an important step in modernizing education without losing cultural identity.

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APPENDIX 1

Pretest and Posttest Instrument

1. *Gending Lancaran* has a complex but regular rhythmic pattern in the Javanese music tradition. You are asked to analyze the beat patterns of the main instruments: *gong*, drum, and *saron*, in a single cycle of 16 beats. The rules of the sound are as follows:
   - Gong: Sounds every 8 beats
   - Drums: Sound every 4 beats
   - Saron: Sounds every 2 beats.

   However, a musician wanted to add a new instrument, *kenong*, with the rule that it sounds in multiples of prime numbers in a cycle of 16 beats.

   a. Create a structured beat table based on the sound rules for each instrument in a 16-beat cycle.
   b. Analyze which beat patterns produce sounds simultaneously
   c. Which beats sound simultaneously to two instruments? List those beats
   d. Which beats sound simultaneously to three instruments? List those beats

2. In the Javanese culinary tradition, Mr. Dalang's family makes *jenang* (traditional Indonesian sweets) for traditional events. After the *jenang* is finished cooking, they pack it to be distributed to the guests. They pack according to the following rules:
   - *Jenang* is put in a banana leaf. Each package of banana leaves contains 8 pieces of *jenang*. If the remaining *jenang* is less than 8 pieces, *jenang* is left unwrapped.
   - The banana leaf wrapper will be put into a bamboo basket. Each basket contains 8 packs. If the number of banana leaf wrappers left is less than 8, the remaining wrappers are not put in the basket.

   Today, Mr. Dalang's family makes 275 pieces of *jenang*. How many pieces of *jenang* are not wrapped in banana leaves?

3. An amusement park offers tickets at promotional prices that change monthly following a specific pattern of increases. In the first month, the ticket price is IDR 80,000; in the second month, it is IDR 85,000; and in the third month, it is IDR 90,000.
   a. Abstract the pattern of ticket price increases into a general formula to calculate ticket prices in the nth month. Describe your steps in compiling this formula.

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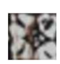
b. Use this formula to determine the ticket price in the 15th month without manually calculating it month by month.
c. If the theme park has a target to sell tickets for IDR 200,000, in what month will this target be achieved? Describe your calculation process.

4. An art festival is held for 10 consecutive days. On the first day, 200 visitors attended the festival. The number of visitors increases daily in a specific pattern, namely 20% from the previous day.
   a. Design a step-by-step algorithm that can be used to count the number of visitors on day 10.
   b. Explain how the algorithm can be modified if the pattern of increasing the number of visitors changes to a fixed increase of 50 people per day

5. A Batik artist is designing a Batik *Cepoko Kotak Besar* motif by using repeating geometric patterns. At first, he made the motif in small sizes, as seen in the first image. Then, he zoomed in on the pattern by adding new elements to each level, as seen in the second and third images.

   a. Without drawing, how many motif patterns  are there in the 10th pattern?
   b. In the 10th pattern, how many motif patterns  are there?
   c. In the 12th pattern, how many motifs patterns  are there?

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APPENDIX 2

Lesson Plan of Number Pattern Based on RME

General Information	
Education Level	Junior High School
Mathematics Topic	Number Pattern
Class	VIII
Time Allotment	12 x 40 minutes (6 meetings)
Instructional Outcomes	**Instructional Objective**
At the end of the lesson, students can recognize, predict, and generalize patterns in the form of the arrangement of objects and numbers	• Students can generalize patterns and rows of numbers using tables correctly • Students can generalize the pattern of an object configuration correctly
Facilities and Infrastructure	
LCD projector, computer, markers, eraser, whiteboard, tables, chairs, and colorful folding paper	
Instructional Model	**Instructional Media**
Realistic Mathematics Education Lecture and Discussion	Chairs, and colorful folding paper
Instructional Activities (First Meeting)	
Pre-Activity	
• The teacher opens the learning with greetings and prayers together • Teachers check the attendance of students as a form of discipline • The teacher conveyed the learning objectives at the meeting • The teacher informed the assessment technique, namely, the pretest work	
In-Activity	
Teacher's Activity	**Pupil's Activity**
• The teacher provides a pretest to find out the initial ability of the students	• Students work on a pretest given by the teacher
Post-Activity	
• Teachers and students reflect on meeting learning 1 • The teacher informed about the learning that would be carried out at the next meeting, namely the number pattern	
Instructional Activities (Second Meeting)	

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<table>
<tr><th colspan="3">Pre-Activity</th></tr>
<tr><td colspan="3">The teacher opens the learning with greetings and prayers together.
Teachers check the attendance of students as a form of discipline.
The teacher gave an overview of the benefits of studying number patterns daily.
The teacher conveyed the learning objectives at the meeting.
The teacher introduces the realistic context, namely, the arrangement of class seats.
The teacher explained that learning uses the RME approach.</td></tr>
<tr><th colspan="3">In-Activity</th></tr>
<tr><th>Emergent Modeling Activity</th><th>Teacher's Activity</th><th>Pupil's Activity</th></tr>
<tr><td>Contextual Problem</td><td>Instruct students to form 5 groups
Convey a real scenario:
"We will arrange a chair in the classroom for a performance or event."
Asking the lighter question:
"If the first row contains 3 seats, what about the second row? Third? The 10th row?"
Invite students to pay direct attention to the chairs in the classroom as learning objects</td><td>Observe examples of real seating arrangements in the classroom
Predict the number of seats in each row based on real observations
Write down initial ideas or conjectures about the pattern of chair arrangement</td></tr>
<tr><td>Contextual Exploration</td><td>Instruct students to arrange classroom seats according to instructions (e.g., first row 3 seats, second row 5 seats, etc.).
Directing students to record the results of observations in a table systematically.
Ask a question:
"What changes from one line to the next?"
"Is there a fixed pattern in the arrangement of the chairs?"</td><td>Lift, move, and arrange the original chairs in the classroom in groups.
Record the number of seats per row and fill in the table.
Discuss in groups: the increase in the number of seats, the shape of the arrangement, and the patterns that appear.</td></tr>
</table>

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<table>
<tr><td>Concept Formulation</td><td>Facilitate discussions between groups to compare results.
Directing students concludes that the number of seats increases regularly (e.g., +2 per row).
Conveying mathematical terms such as "arithmetic rows".</td><td>Presenting the group's findings based on the arrangement of the chairs they made.
Explain the pattern of changes in the number of seats and try to write in verbal form (words).
Draw initial conclusions collectively.</td></tr>
<tr><td colspan="3">Post-Activity</td></tr>
<tr><td colspan="3">The teacher closes the first meeting by greeting the students and leading a prayer.
The teacher informs the students that the learning will continue in the third meeting</td></tr>
<tr><td colspan="3">Instructional Activities (Third Meeting)</td></tr>
<tr><td colspan="3">Pre-Activity</td></tr>
<tr><td colspan="3">The teacher opens the learning with greetings and prayers together
Teachers check the attendance of students as a form of discipline
The teacher informed that today's learning continued the activities from the previous meeting
The teacher informed that the assessment was carried out through the work on the student's activity sheet</td></tr>
<tr><td colspan="3">In-Activity</td></tr>
<tr><td>Emergent Modeling Activity</td><td>Teacher's Activity</td><td>Pupil's Activity</td></tr>
</table>

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Mathematization	• Guiding students to convert verbal patterns into mathematical notation. • Ask questions like: *"Can you write down the general formula for the number of seats in the nth row?"* • Provide feedback on mathematical formulas or expressions that students have compiled. • Provide additional examples to test the accuracy of the student's formula	• Trying to formulate a general formula from the observed pattern • Use the formula to calculate the seats in the 10th, 15th, etc. rows. • Revise the formula, if necessary, based on the calculation results. • Explain the math process to a group or class friend
Generalization	• Provide a variation of real context, for example, the seating arrangement in the school hall. • Encourage students to compile their contextual problems using the formulas provided.	• Solve advanced questions based on the formula they made. • Creating new similar problems based on the experience of arranging chairs. • Finding relationships between context and number patterns.
Reflection and Evaluation	• Invite students to reflect on today's learning process: *"What did you guys learn about the chair pattern today?"* *"Which part is the most challenging?"* • Provide feedback directly to each group or student. • Close the lesson by summarizing the process from start to finish.	• Write down personal reflections as notes or exit tickets. • Deliver a memorable or confusing learning experience. • Give feedback to your groupmates. • Answer the teacher's questions honestly and openly.

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Instructional Activity (Fourth Meeting)		
Pre-Activity		
• The teacher opens the learning with greetings and prayers together. • Teachers check the attendance of students as a form of discipline. • The teacher conveyed the learning objectives at the meeting. • The teacher reminds students of the previous material and relates it to the material to be studied • The teacher introduces the realistic context, namely, folding the paper.		
Activity	**Teacher's Activity**	**Pupil's Activity**
Contextual Problem	• Conveying the real situation: *"Imagine you fold the paper in half, then fold it again, and keep folding."* • How many parts are formed after several folds?" • Show examples of colorful folding paper and demonstrate the first and second folds. • Asking open-ended questions: *"What happens to the number of pieces of paper each time it is folded?"*	• Pay attention to the paper that the teacher folds. • Gives an initial guess of the number of parts formed after a few folds. • Record initial answers individually as a pattern prediction
Contextual Exploration	• Distribute colorful folding paper to each student or group • Giving instructions: *"Fold the paper into two parts, then four, and so on, up to a maximum of 5 times."* • Have students record the number of parts each time the fold is performed.	• Fold the paper repeatedly according to the instructions. • Count and record the number of paper parts after each fold. • Discussion in small groups to recognize the growth pattern of the number of parts

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<table>
<tr><td></td><td>Guiding students to fill out tables of n-fold and the number of sections</td><td></td></tr>
<tr><td>Concept Formulation</td><td>Facilitate discussions between groups regarding the pattern of paper parts.
Ask:
"How many parts if folded 6 times? 7 times?"
"What changed? What's fixed?"
Introduce the concept of exponential growth if students haven't already been introduced.</td><td>Discuss the results of the table and compare them between groups.
Realize that the number of parts is always double what it was before
Conveying that the patterns that appear are: 2, 4, 8, 16, 32...
Try to write a pattern in the form of a sentence and draw an initial conclusion.</td></tr>
<tr><td colspan="3">Post-Activity</td></tr>
<tr><td colspan="3">The teacher closes the first meeting by greeting the students and leading a prayer.
The teacher informs the students that the learning will continue in the fifth meeting.</td></tr>
<tr><td colspan="3">Instructional Activities (Fifth Meeting)</td></tr>
<tr><td colspan="3">Pre-Activity</td></tr>
<tr><td colspan="3">The teacher opens the learning with greetings and prayers together.
Teachers check the attendance of students as a form of discipline.
The teacher informed that today's learning continued the activities from the previous meeting
The teacher informed that the assessment was carried out through the work of the student's activity sheet</td></tr>
<tr><td>Activity</td><td>Teacher's Activity</td><td>Pupil's Activity</td></tr>
<tr><td>Mathematization</td><td>Guiding students to formulate a general formula of the number of parts as a function of the nth fold:
"Try to write this pattern as a formula. For example, B(n) = ...?"
Provide additional training:
"How many parts if folded 10 times?"</td><td>Compiling the general formula: $B(n) = 2^n$
Use the formula to calculate the number of paper parts after 6, 8, and 10 folds.
Testing the accuracy of formulas with table data.</td></tr>
</table>

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<table>
<tr><td></td><td>• Associate the formula found with the exponential</td><td>• Convey the process of discovering formulas orally and in writing.</td></tr>
<tr><td>Generalization</td><td>• Asking follow-up questions based on predictions:
"How many parts are formed if it can be folded 20 times?"
• Providing new context:
"What if the folding is done vertically and horizontally alternately?"
• Encourage students to make their variations based on patterns.</td><td>• Apply formulas to solve predictive problems.
• Develop a variety of folds by creating your problems.
• Test and compare the results of vertical and horizontal folding.
• Demonstrate an understanding of generalizations outside of the initial context.</td></tr>
<tr><td>Reflection and Evaluation</td><td>• Invite students to reflect on the learning process through questions:
"What did you learn from folding paper?"
" What are the advantages of using this activity to understand number patterns?"
• Provide individual or group feedback.</td><td>• Conveying reflections: what's easy, what's challenging.
• Fill out a reflection journal or answer open-ended questions.
• Explain how they can recognize and formulate real activities.</td></tr>
<tr><td colspan="3">Instructional Activity (Sixth Meeting)</td></tr>
<tr><td colspan="3">Pre-Activity</td></tr>
<tr><td colspan="3">• The teacher opens with an opening greeting and prays to start learning
• The teacher checks the presence of students as a disciplined attitude
• Convey the objectives of the learning at the ongoing meeting
• Inform the assessment technique, namely, posttest work</td></tr>
<tr><td colspan="3">In-Activity</td></tr>
<tr><td colspan="2">Teacher's Activity</td><td>Pupil's Activity</td></tr>
<tr><td colspan="2">• The teacher gives a posttest to find out the final ability of the students</td><td>• Students work on the posttest given by the teacher</td></tr>
<tr><td colspan="3">Post-Activity</td></tr>
</table>

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• The teacher closes the first meeting by greeting the students and leading a prayer • Teachers and students reflect on the whole learning process

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APPENDIX 3

Student Worksheet Based on RME

Member Name:
1.
2.
3.
4.
5.

Class:

Activity 1: Contextual Problem

Imagine that you are preparing for an important event in class, such as an art performance, a class meeting, or a small performance. For this reason, you need to arrange the seats so that all participants can sit neatly and comfortably. Your teacher gives instructions on how to set up the chair.

The following are the rules for setting up the seats:

- In the first row, the chairs are arranged as many as 3 pieces.
- In each next row, the number of seats increased by 2 seats compared to the previous row.

Activity Instructions:

1. Pay close attention to the seat arrangement instructions above.
2. Try to imagine or organize it in real life in your class if possible.
3. Predict and record how many seats there are in the second, third, fourth, and so on.
4. Write down your observations in the table below.

Initial Questions:

- If there are 3 seats in the first row, how many seats are in the second row?
- What about the third row?
- Then, how many seats will there be in the 10th row?

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Write down your initial idea (can be in the form of a sentence):

Activity 2: Contextual Exploration

Now, let's experiment with it live!

- **Instruction**

In groups, lift, move, and arrange your classroom chairs according to the instructions:

- The first row contains 3 seats.
- The second row increased by 2 seats from the previous row.
- The third row adds another 2 seats, and so on.
- Arrange it up to the 6th row

Activity 3: Concept Formulation

After you have arranged the chairs in the classroom with the teacher, now continue by filling in the following Table 1 based on your observations. Pay close attention to how many chairs are in each row, and what the pattern of increase is!

Table 14. Observation of Chair Arrangement

Row	Number of Seats	Difference from Previous Row
1		
2		
3		
4		
5		
6		

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Discussion

- What changes from one row to the next?
- Is there a pattern in the change in the number of seats?
- Try to describe the pattern of change in your own words.

Activity 4: Mathematization

Introducing the Concept of the n-th term

Before creating a formula, let's first understand the "term" in a number pattern!

- The first term (n = 1) is the number of seats in the first row or can be symbolized by U_1
- The second term (n = 2) is the number of seats in the second row, or it can be symbolized by ....
- The third term (n = 3) is the number of seats in the third row, or can be symbolized by ....
- The fourth term (n = 4) is the number of seats in the fourth row, or can be symbolized by ....
- The fifth term (n = 5) is the number of seats in the fifth row, or can be symbolized by ....
- The sixth term (n = 6) is the number of seats in the sixth row, or can be symbolized by ....

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Table of Terms Number of Seats:

n (row number)	Number of seats
U_1	
U_2	
U_3	
U_4	
U_5	
U_6	

Identifying the Relationship Between Terms

Observe how the terms are related:

- From the first term to the second term, the number of seats increases by ______.
- From the second term to the third term, the number of seats increases by ______.
- From the third term to the fourth term, the number of seats increases by ______.
- From the fourth term to the fifth term, the number of seats increases by ______.
- From the fifth term to the sixth term, the number of seats increases by ______.

Question:

- **Is there an increase in the number of seats each time it stays?**

  Answer:

- **How much does it increase?**

  Answer:

Developing a General Pattern

Pay attention to the results of the table. If the increment is always fixed, then you can write:

- Second term = first term + _______
- Third term = second term + _______

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- Fourth term = third term + _______
- Fifth quarter = fourth quarter + _______
- Sixth quarter = fifth quarter + _______

From that pattern, try writing:

General pattern:

"The number of seats in the n row is obtained by adding ____ seats to the number of seats in the previous row."

Create an Explicit Formula

Now, compile the general formula for the number of seats on the 6th row:

- Lots of starting seats = 3
- Each increases 2 seats for each row increase

So:

U_n = ... + (n - 1) × ....

U_n = ……………………..

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Activity 5: Generalization

- Formula Trials

Use the n-th formula to calculate:

Number of 10th rows

Number of 25th rows

Number of 55th rows

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EXERCISE

The picture above is one of the Batik motifs from the Yogyakarta Palace, Indonesia, namely the Batik *Grompol* motif. The Batik *Grompol* motif has a characteristic in the form of a geometric pattern that is neatly arranged and uniform, similar to a grid or grid pattern. Notice the arrangement of motifs  below that make up the square number pattern!

Mr. Andi, a Batik *Grompol* maker, made a motif in which the number of ornaments on each row and column followed a square number pattern. In the first row, there are 1 ornament, in the second row, there are 4 ornaments, in the third row, there are 9 ornaments, and so on.

a. How many ornaments does Mr. Andi use if he completes the Batik *Grompol* motif up to the 20th row?
b. What is the total ornament from the 1st to 10th row?
c. Create a nth formula based on the case

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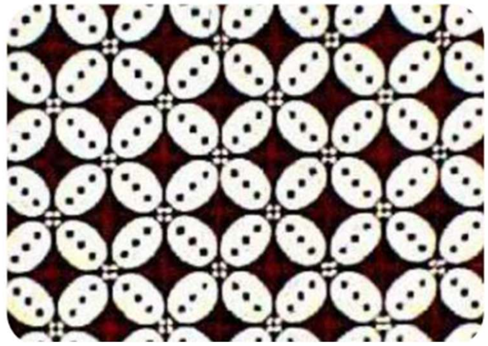

The picture above is one of the Batik motifs from Yogyakarta, namely the Batik *Kawung* motif. The Batik *Kawung* motif with its geometric pattern consisting of circles that cross each other, can be represented as a form of a rectangular number pattern. Notice the arrangement of motifs  below that make up the rectangular number pattern!

Ani wanted to make a handkerchief from a cloth with a Batik *Kawung* pattern. He wanted to make the handkerchief with a precise size, so that each motif was perfectly formed and not cut.

a. If one motif on a fabric is 2x2 cm in size, how much area is the fabric formed if the largest number pattern that can be loaded is the 6th pattern of the rectangular number pattern?
b. Create a nth formula based on the case

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Member Name:
1.
2.
3.
4.
5.

Class:

Activity 1: Contextual Problem

- **Scenario:**
  Imagine you have a standard sheet of paper. Each time you fold it in half, the number of layers doubles.

- **Instructions:**
  1. Take a sheet of paper.
  2. Fold it in half once.
  3. Unfold and observe the number of layers.
  4. Repeat the folding process up to four times, folding the paper in half each time.
  5. After each fold, record the total number of layers.

- **Initial Questions:**
  - How many layers are there after the first fold?
  - How many layers are there after the second fold?
  - What about the third fold?
  - Can you predict the number of layers after the 10th fold?

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Write down your initial ideas:

Activity 2: Contextual Exploration

- **Objective:**
  Engage students in hands-on exploration to observe the pattern of exponential growth.

- **Instructions:**
  1. In groups, perform the paper folding activity as described.
  2. After each fold, count and record the number of layers.
  3. Discuss within your group the pattern you observe.

Activity 3: Concept Formulation

Objective:
Identify and articulate the pattern observed in the paper-folding activity.

Table 1: Observation of Paper Folding

Fold Number (n)	Number of Layers	Difference from Previous Fold

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Discussion Questions:

- **What changes from one fold to the next?**
- **Is there a pattern in the change in the number of layers?**
- **Try to describe the pattern of change in your own words.**

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Activity 4: Mathematization

Objective:
Develop a mathematical formula to represent the observed pattern.

Understanding the Terms:

- First term (n = 1): $U_1 = 2$
- Second term (n = 2): $U_2 = 4$
- Third term (n = 3): $U_3 = 8$
- Fourth term (n = 4): $U_4 = 16$

Notice the ratio between two adjacent terms!

$$\frac{U_2}{U_1} = \frac{\dots}{\dots} = \dots$$

$$\frac{U_3}{U_2} = \frac{\dots}{\dots} = \dots$$

$$\frac{U_4}{U_3} = \frac{\dots}{\dots} = \dots$$

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Questions:

Is the ratio between two adjacent terms always the same?

Answer:

Suppose the first term = U_1 and ratio = r, so

n-th term	Value	Multiplication	Common Forms
1	2	-	U_1
2	4	2×2	$U_2 \times r$
3	8	$2 \times$ …………	$U_3 \times r^{\cdots}$
4	16	$2 \times$ …………	$U_4 \times r^{\cdots}$

From that pattern, try writing:

General pattern:

"The number of paper folds in row n is found by multiplying the number of folds in the previous row by the ratio ____ "

Create an Explicit Formula

Now, compile the general formula for the number of paper layers after the nth fold:

- First term: a = 2 (after the first fold, there are 2 layers)
- Common ratio: r = 2 (each fold doubles the number of layers)

So, the general formula is:

U_n = ……..× ……..

U_n = ……..× ……..

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Activity 5: Generalization

- Formula Trials

Use the n-th formula to calculate:

Number of 5th rows

Number of 7th rows

Number of 8th rows

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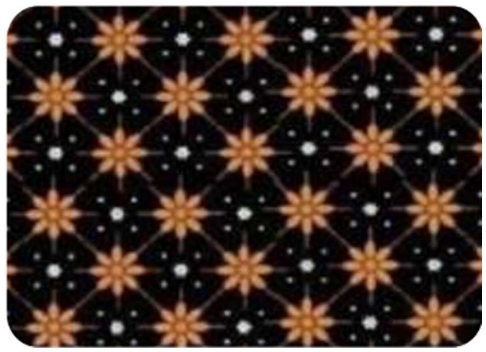
EXERCISE



The picture above is one of the Batik motifs from Yogyakarta. Batik *Truntum*, with an irregular flower pattern, can be interpreted as a form of a triangular number pattern. In this case, we can pay attention to the arrangement of the flowers and identify the growth patterns associated with the number of triangles. Take a look at the arrangement of motifs below that make up the triangle number pattern!

Mr. Joko, a Batik craftsman in Yogyakarta, is making Batik *Truntum* motifs with ornamental arrangements that form triangles. In the first row there are 1 ornaments, in the second row there are 3 ornaments, and in the third row there are 6 ornaments, following the pattern of triangle numbers.

a. How many ornaments are there in total if Mr. Joko completes the Batik *Truntum* motif up to the 17th row?
b. Make an nth formula based on the case!

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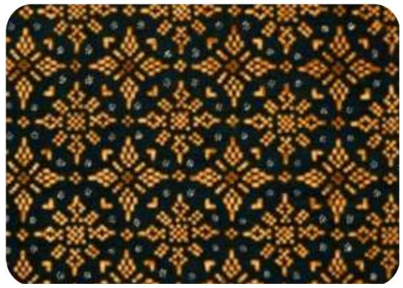

The picture above is one of the Batik motifs from Yogyakarta, namely *Nitik* Batik motifs. The Batik *Nitik* motif depicts an odd number pattern through an arrangement of dots that form an orderly geometric pattern. Notice the arrangement of motifs below that form an odd number pattern!

A Batik *Nitik* artisan in Yogyakarta is designing a new motif that follows an odd number pattern to arrange the dots on the Batik fabric. In such a design, each row has many points that follow a sequence of odd numbers.

a. If each point takes 2 minutes to draw, how long does it take to complete the Batik *Nitik* motif to the 10th row?
b. Is this time realistic to complete in a day? Explain your reasons

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