

Analyzing students' computational thinking and math reasoning via PISA-based learning

Mutiara Annisa Widodo * , Marsigit, Galih Pranowo

Universitas Negeri Yogyakarta, Indonesia.

* Corresponding Author. E-mail: mutiaraannisa18@gmail.com

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ABSTRACT

Computational thinking and mathematical reasoning abilities are crucial 21st century skills. However, the results of international studies show that these abilities are still low in Indonesian students. This study aims to test the effectiveness of PISA-based learning in improving the computational thinking and mathematical reasoning abilities of junior high school students. The PISA Principles are a learning guide released by the OECD to produce globally competent students. The study used a quasi-experimental design with two groups of grade VII junior high school students as subjects. The experimental group received a contextual-based PISA principle learning method, while the control group followed the conventional learning method. The research instrument was a computational thinking and mathematical reasoning ability test. Data were analyzed using a two-sample t-test. The results showed that the contextual-based PISA principle learning method was effective in improving students' mathematical reasoning abilities but was less effective for computational thinking abilities. These findings can be a reference in designing mathematics learning relevant to the demands of the 21st century. The recommendation from the results of this study is the need for instrument adaptation to measure the dimensions of computational thinking that are more specific to the four main indicators, namely: decomposition, pattern recognition, abstraction and algorithms.



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INTRODUCTION

The demands of the 21st century require a fundamental transformation in mathematics education, particularly in developing students' computational thinking and mathematical reasoning skills. These abilities are not merely academic competencies but are essential prerequisites for addressing the complexity of an increasingly dynamic global landscape that calls for advanced thinking skills (Grover & Pea, 2018; Weintrop et al., 2016; Csapó & Molnár, 2019). Computational thinking and mathematical reasoning form the foundation of mathematical literacy, enabling students to think logically, systematically, and critically in solving complex problems beyond mere numerical computation (Lockwood et al., 2022; Jeannotte & Keiran, 2017; Benton et al., 2018). However, the current state of mathematics education in Indonesia reveals a considerable gap between potential and actual practice in fostering these abilities.

Computational thinking is a fundamental skill required by all individuals. It encompasses problem-solving, system design, and understanding human behavior by applying core concepts of computer science (Wing, 2006; Kong, 2019; Zhang & Nouri, 2019). It involves decomposing problems into smaller components, identifying key and relevant elements, recognizing patterns, and planning solutions most efficiently (Yadav, 2014; Barr & Stephenson, 2011; Denning, 2017). In mathematics education, computational thinking helps nurture computational competencies and shifts students' perspectives from viewing mathematics solely as finding correct answers to appreciating its complexity and the existence of multiple solutions (Maharani et al., 2020; Shute et al., 2017; Perez-Marin et al., 2020). Supiarmo et al., (2021) outlined the indicators of computational thinking, including: (1) decomposition (interpreting information and simplifying problems, converting verbal to numerical data, identifying relevant formulas); (2) pattern recognition (identifying problems and recognizing potential patterns); (3) abstraction (focusing on essential information and devising problem-solving strategies); and (4) algorithm design (executing problem-solving steps and drawing conclusions).

Despite its importance, computational thinking skills among Indonesian students remain relatively low. A computational thinking assessment by Kamil et al., (2021) revealed substandard performance, with students scoring well below the minimum proficiency threshold (KKM), attaining a maximum score of only 68.75 and an average of 33.25, against a KKM of 79. The lowest performance was noted in pattern recognition, while decomposition was hindered by students' inability to identify given and required information clearly. Similarly, weaknesses in abstraction and algorithmic accuracy were observed (Azizah et al., 2022).

Comparable challenges are reported internationally. In Finland, Kalelioglu et al., (2019) noted difficulties in integrating computational thinking into the curriculum despite its formal inclusion. In the UK, Sentence & Csizmadia (2017) highlighted teachers' struggles to convey computational concepts in mathematical problem-solving. In Singapore, Kong et al., (2020) observed students' difficulties in transferring computational skills across disciplines. In Spain, Roman-Gonzalez et al., (2018) found disparities in computational thinking across socio-economic groups. Similarly, in Brazil, Brackmann et al., (2019) documented students' limited abstraction and algorithm generalization skills both crucial aspects of computational thinking.

Reasoning is a cognitive process used to derive new conclusions from existing information (Wibowo, 2022; Mercier & Sperber, 2017). In the context of mathematics, reasoning is reflected when students engage in questioning and justification by asking: Is it true? How can I be sure? Why is it true? (Brodie et al., 2010; Mata-Pereira & da Ponte, 2017; Reid & Knipping, 2021). Sumarmo (2018) identified several key indicators of mathematical reasoning, including: drawing logical conclusions; providing explanations based on models, facts, and relationships; estimating results and processes; identifying patterns and relationships; formulating and testing conjectures; constructing counterexamples; applying rules of inference and validating arguments; and developing both direct and inductive proofs. Similar emphasis on logical argumentation and justification is echoed (Stylianides, 2016; Herbert et al., 2019).

Global assessments have consistently highlighted Indonesia's poor performance in mathematics. The 2018 PISA results ranked Indonesia 72nd out of 78 countries in mathematical literacy, significantly below the OECD average (OECD, 2019). TIMSS 2019 similarly placed Indonesia 45th out of 58 countries in mathematical proficiency (Mullis et al., 2020). Domestic studies also confirm these findings. Vebrian et al., (2021) reported low achievement across indicators such as conjecturing, mathematical manipulation, and justification, with mastery levels around 42.88% dropping even further for concluding (41.36%). Izzah & Azizah (2019) similarly found that most students' reasoning skills remain in the low or very low category.

Other countries also face similar issues. In Malaysia, Zulnaldi et al., (2020) found challenges in both deductive and inductive reasoning. In South Africa, Venkat et al., (2021) highlighted students' difficulty articulating logical arguments. Turkish students, according to Aydin & Ubuz (2022), struggled particularly in validating mathematical evidence. In the U.S., Thompson et al., (2017) noted challenges in applying quantitative reasoning to non-routine problems. Collectively, these findings suggest a global need to reform pedagogical approaches toward more contextual and adaptive models.

Given the observed deficiencies, there is a pressing need for effective learning models to enhance students' reasoning and computational thinking. In this context, the present study adopts the PISA-based contextual learning model to investigate its potential in addressing these gaps. The research was conducted in a state junior high school in Piyungan, Bantul, Yogyakarta, representative of semi-urban Indonesian schools and their typical educational challenges.

The PISA principle emphasizes four pillars: (1) learning involves not only teachers and students but also broader social and global contexts; (2) learning should address relevant local, global, and intercultural issues through meaningful understanding; (3) teachers play a critical role in designing quality learning experiences, anticipating obstacles, and fostering a global learning environment; (4) students are encouraged to respond adaptively and provide feedback to foster global and intercultural learning (OECD, 2019; Schleicher, 2022). These foundations align with broader goals of building global competencies (Salzer & Roczen, 2018; Care et al., 2018), though implementation results vary across countries depending on local educational readiness (Tan et al., 2021; Meyer & Benavot, 2013). Nilsen (2016) further emphasizes that the successful adoption of PISA principles is contingent upon systemic educational reform.

This study thus proposes the application of the PISA principles as a strategic pedagogical intervention. According to Mansilla & Schleicher (2022), globally competent students must integrate various knowledge domains, employ critical reasoning, and adapt their communication to diverse social contexts. Teachers are tasked with designing engaging, relevant, and effective learning experiences that incorporate real-world, contextual, and cross-cultural issues. This approach does not merely change teaching techniques it embeds contextual, analytical, and problem-solving paradigms within mathematics instruction (Gravemeijer et al., 2017; Schoenfeld, 2016; Lithner, 2017). The effectiveness of this strategy depends on educators' ability to select meaningful issues and align learning objectives with global literacy and reasoning skills.

In this study, the topic of comparative and inverse values was chosen due to its high relevance to daily life and its applicability in various real-world contexts, consistent with PISA principles. This material fosters logical thinking, presents appropriate cognitive challenges, and enables innovative instructional design rooted in contextual learning (Lamon, 2020; Lobato et al., 2021).

The novelty of this research lies in employing PISA principles to develop students' mathematical reasoning and computational thinking holistically, focusing on the formative stage of junior high school where such skills begin to solidify (English & Gainsburg, 2016; Grgurina et al., 2018). The quasi-experimental design enables a systematic and measurable evaluation of pedagogical impact. Compared to prior studies, this research stands out for its structured methodology, comprehensive assessment tools, and orientation toward 21st-century competencies.

Ultimately, this study contributes to the development of innovative, PISA-based instructional models, provides empirical evidence of their effectiveness, and offers a conceptual foundation for mathematics curricula aligned with global standards. As such, it presents both scholarly value and practical solutions for transforming mathematics education in Indonesia to meet international expectations.

METHOD

Research Objectives

This study aims to: 1) examine the influence of the learning method on students' mathematical reasoning and computational thinking abilities; 2) evaluate the effectiveness of the contextual-based PISA principles learning method in enhancing students' mathematical reasoning abilities; 3) evaluate the effectiveness of the contextual-based PISA principles learning method in enhancing students' computational thinking abilities.

Research Subjects

The subjects of this study were 64 seventh-grade students from a public junior high school in Piyungan, Bantul, Yogyakarta Special Region (DI Yogyakarta). The participants were divided into

two groups: 32 students in the experimental group and 32 in the control group. A purposive sampling technique was employed, considering the equivalence of students' initial abilities. The research was conducted during the first semester of the 2023/2024 academic year.

Research Procedure

This study employs a quantitative approach with a quasi-experimental research design. This design was selected because the sample groups used were pre-existing classroom groups formed during regular school activities. The study adopts the Two Equivalent Groups Posttest-Only Design, in which the experimental and control groups are assumed to have equivalent baseline conditions. The research procedure consists of the following stages: 1) preparation and development of research instruments; 2) instrument validation; 3) implementation of learning in the experimental group using context-based PISA principles over six sessions; 4) administration of the post-test; 5) data analysis. The following is the research flow diagram:

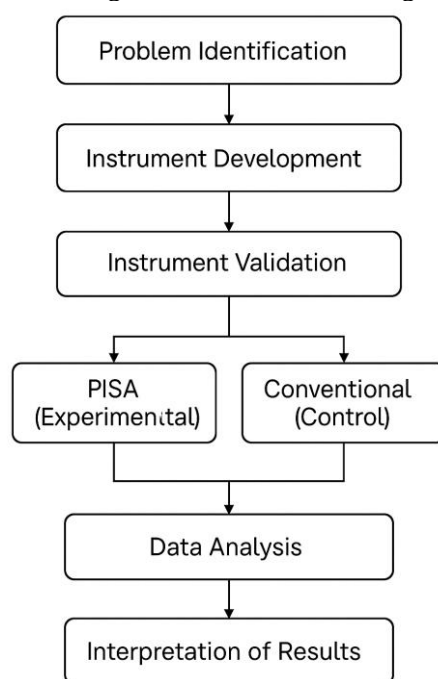


Figure 1. Research Flowchart

Research Data and Instruments

The data collected in this study were in the form of students' mathematical reasoning and computational thinking ability scores. In the computational thinking test, the instrument used was 8 questions with the following grid details:

Table 1. Computational Thinking Test Instrument Grid

Aspects Measured	Indicator	PISA Principles	Question Type	Question Number
Observe patterns and focus on the important information	Students can answer questions related to the application of equivalent comparisons in real-life situations	Involves issues or contexts that are relevant to everyday life, such as the time it takes to fill a bathtub with water, the height of the water in the bathtub, and the relationship between the two, both descriptively and abstractly	Multiple Choice	2
Determine the steps needed to solve a problem.	Students can determine the equivalent comparison codomain values		Multiple Choice	3

Determining what steps are needed to solve a problem	when the domain is known Students can solve problems involving the application of inverse ratios in everyday situations	Involves relevant everyday issues or contexts that may not be familiar to all students, such as the relationship between the number of cows on a farm, the amount of feed, and the time it takes to consume the feed.	Essay	6
Observing patterns and seeing similarities	Students can determine the domain and codomain of inverse comparison values presented in a table.	Involves relevant issues or contexts on a more global scale, such as race tracks and travel time	Table Fill	8
Observing patterns and focusing on important information	Students can draw a graph comparing inverse values		Drawing a Graph	11
Focus on important information.	Students can draw a comparison graph of values	Involves relevant everyday issues or contexts, such as cake making	Drawing a Graph	12
Observing Patterns	Students can draw a comparison graph of values		Identify a Graph	13
Observing patterns	Students can draw a graph comparing inverse values.	Focuses on deep understanding	Identify a Graph	14

The students' mathematical reasoning test consists of 10 questions, with the following detailed grid:

Table 2. Mathematical Reasoning Test Instrument Grid

Aspect Measured	Indicator	PISA Principles	Question Type	Question Number
Drawing Logical Conclusions	Students can comprehend the concept of comparative value	The learning process incorporates issues and contexts relevant to everyday life (such as wage calculation, time required to complete a task, vehicle speed, travel distance, and time allocated for feeding and the number of animals) to address students' learning challenges in understanding the concepts of comparative and inverse values	True / False	1
Estimating Answers and Solution Processes	Students can respond to questions involving the application of equivalent comparisons in real-life situations.		Multiple Choice	2
Using Patterns and Relationships to Analyze	Students can determine the corresponding codomain values in equivalent comparisons	Involving Relevant Everyday Contexts The context involves real-life situations such as the time required to fill a	Multiple Choice	3

Mathematical Situations and Predict Answers and Solution Processes	when the domain values are known.	bathtub with water, the height of the water in the bathtub, and the relationship between these two variables, both descriptively and abstractly.		
Estimating Answers and Solution Processes	Students can determine the equation that represents the relationship between pairs of equivalent comparative quantities.		Multiple Choice	4
Providing Explanations Using Relationships	Students can explain the relationship between pairs of co-varying quantities using clear and coherent written statements.		Multiple Choice	5
Estimating answers and solution processes	Students can answer questions related to the application of inverse ratios in everyday life.		Essay	6
Constructing valid arguments, providing explanations with relationships	Students can understand the concept of inverse value comparisons	Involving relevant issues or contexts from everyday life that may not be familiar to all students, such as the relationship between the number of cows on a farm, the amount of feed, and the time it takes to finish the feed. Deep learning occurs when students can provide appropriate reasoning for the answers they give	Essay	7
Estimating answers and solution processes	Students can solve problems involving the application of inverse ratios in everyday life.		Short Answer Question	9
Estimating answers and solution processes	Students can determine the equation that represents the relationship between pairs of equivalent comparative quantities.		Short Answer Question	10
Students use patterns and relationships to analyze and make sense of mathematical situations.	Students can draw a comparison graph of values	Involves relevant everyday issues or contexts, such as cake making	Drawing a Graph	12

Validity and Reliability of the Instrument

The validity evidence used in this study includes content validity and construct validity. Content validity was established through expert judgment by two experts in the field of mathematics education. The instrument is considered valid if the expert evaluations indicate so. Construct validity was assessed using the point-biserial correlation formula for items with dichotomous scores (0 or 1), and the product-moment correlation formula for essay questions with varying scores.

An item is considered valid if the calculated correlation coefficient (r count) is greater than the critical value from the r table. Based on the validation results, the instrument is considered valid in both content and construct for use with a sample of 64 students. For $N = 64$ at a 5% significance

level, the r table value is 0.24. Content validity was confirmed with revisions, and construct validity was supported as shown in Tables 3 and 4:

Table 3. Construct Validity of Computational Thinking Questions

Number	2	3	6	8	11	12	13	14
r table	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24
r hitung	0.57	0.67	0.55	0.50	0.46	0.35	0.43	0.57
	Valid	Valid	Valid	Valid	Valid	Valid	Valid	Valid

Table 4. Construct Validity of Mathematical Reasoning Questions

Number	1	2	3	4	5	6	7	9	10	12
r table	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24
r count	0.54	0.47	0.44	0.43	0.43	0.42	0.46	0.51	0.42	0.43
	Valid	Valid	Valid	Valid	Valid	Valid	Valid	Valid	Valid	Valid

The reliability estimation in this study was conducted using the Cronbach's Alpha formula (alpha coefficient). The instrument is considered reliable if the calculation results show that the r count is greater than the r table value. The following presents the evidence of the reliability of the research instrument:

Table 5. Reliability Estimation

	Mathematical Reasoning	Computational Thinking
r table	0.24	0.24
Alpha Cronbach	0.648	0.622
	Reliable	Reliable

Data Collection Techniques

The data in this study were collected through written tests designed to measure students' mathematical reasoning and computational thinking abilities. The data collection process consisted of the following stages: 1) Developing research instruments for the post-test; 2) Designing the Lesson Plan (RPP) and Student Worksheet (LKS); 3) Validating the instruments and checking their reliability; 4) Revising the instruments based on feedback from expert validators; 5) Conducting the research by administering the treatment to both the experimental and control groups; 6) Administering post-tests to both the experimental and control groups to assess students' mathematical reasoning and computational thinking abilities after the treatment.

Data Analysis Techniques

The data in this study were analyzed using both descriptive and inferential statistical methods. Descriptive analysis was used to describe the results of the learning process based on post-test data on students' mathematical reasoning and computational thinking abilities. The raw scores were converted into a scale ranging from 0 to 100.

Inferential analysis was conducted to generalize findings from the sample to the broader population. The assumption tests included the normality test and the homogeneity test. The normality test used was the Mardia test, which estimates multivariate normality based on skewness and kurtosis. The data are considered multivariate normal if the p -value $> \alpha$ (0.05) in both the skewness and kurtosis tests. The homogeneity of the variance-covariance matrix was tested using the Box's M test. The data are considered homogeneous if the p -value $> \alpha$ (0.05).

Once the assumptions of normality and homogeneity were satisfied, a hypothesis test was conducted using Hotelling's T^2 test to compare the two sample groups. The decision criterion for Hotelling's T^2 test is: H_0 is accepted if the p -value $> \alpha$ (0.05). The hypotheses for this study are as follows:

Table 5. Hypothesis 1

H_0	: There is no significant effect of learning methods on students' computational thinking and mathematical reasoning abilities.
H_1	: There is a significant effect of learning methods on students' computational thinking and mathematical reasoning abilities.

To test the effectiveness of the context-based PISA principle learning model on students' computational thinking and mathematical reasoning abilities, a t-test was conducted. The decision criteria for the t-test are as follows: H_0 is rejected if the p-value $< \alpha = 0.05$. The hypothesis for this study is as follows:

Table 6. Hypothesis 2

H_0	: The context-based PISA principle learning method is not effective in improving students' computational thinking ability.
H_1	: The context-based PISA principle learning method is effective in improving students' computational thinking ability.

Table 7. Hypothesis 3

H_0	: The context-based PISA principle learning method is not effective in improving students' mathematical reasoning ability.
H_1	: The context-based PISA principle learning method is effective in improving students' mathematical reasoning ability.

RESULT AND DISCUSSION

Result

Descriptive Statistics

Statistical data on the computational thinking abilities of students in both the control and experimental groups are presented in [Table 8](#).

Table 8. Statistical Data of Students' Computational Thinking

Statistical Data	Class	
	Control	Experiment
Number of Students	32	32
Average	77.17	84.37
Median	80.43	84.78
Standard Deviation	16.15	11.20
Range	52.18	47.83
Highest Score	100	100
Lowest Score	47.82	52.17
Minimum Possible Score	0	0
Maximum Possible Score	100	100

Based on [Table 8](#), it can be observed that the average computational thinking ability of students in the experimental class (84.37) is higher than that of the control class (77.17). Additionally, the standard deviation in the experimental class (11.20) is smaller than in the control class (16.15), indicating that the variation in student scores is lower in the experimental class. Next, statistical data on students' mathematical reasoning abilities are presented in [Table 9](#).

Table 9. Statistical Data of Students' Mathematical Reasoning

Statistical Data	Class	
	Control	Experiment
Number of Students	32	32
Average	74.84	85
Median	75	85

Statistical Data	Class	
	Control	Experiment
Standard Deviation	13.4	10.21
Range	70	40
Highest Score	95	100
Lowest Score	35	60
Minimum Possible Score	0	0
Maximum Possible Score	100	100

In Table 9, the average mathematical reasoning ability of students in the experimental class (85.00) is higher than that of the control class (74.84). Furthermore, the standard deviation of the experimental class (10.21) is smaller than that of the control class (13.40), suggesting that the distribution of data in the experimental class is more homogeneous. The range of values for the experimental class is also smaller (40) compared to the control class (70), indicating that the learning outcomes in the experimental class are more consistent.

Prerequisite Test

A multivariate normality test was conducted using the Mardia test, assisted by R Studio, with the results presented in Figure 1.

SmultivariateNormality				
	Test	Statistic	p value	Result
1	Mardia Skewness	7.63524311057435	0.105891403821314	YES
2	Mardia Kurtosis	0.0123819386310459	0.990120894765687	YES
3	MVN	<NA>	<NA>	YES

Figure 1. Mardia Normality Test Output

Based on Figure 1, the results of the skewness test yielded a p-value of 0.105 ($> \alpha = 0.05$), and the kurtosis test showed a p-value of 0.99 ($> \alpha = 0.05$). These results indicate that the research data is multivariate normal.

The homogeneity test of the covariance matrix between groups was conducted using Box's M test, assisted by R Studio, with the results shown in Figure 2.

Box's M-test for Homogeneity of Covariance Matrices	
data:	irisdata[, 2:3]
Chi-Sq (approx.)	= 1.5402, df = 3, p-value = 0.673

Figure 2. Box M Homogeneity Test Output

Based on Figure 2, the p-value obtained is 0.673 ($> \alpha = 0.05$), which leads to the conclusion that there is homogeneity of the covariance matrix between groups in the research data.

Hypothesis Test

1. Hypothesis Test 1: The Effect of Learning Methods

To test the effect of learning methods on computational thinking and mathematical reasoning abilities simultaneously, Hotelling's T^2 test was conducted using R Studio. The results of the test are presented in Figure 3.

Hotelling's two sample T2-test	
data:	gabung by zz
T.2	= 4.9007, df1 = 2, df2 = 49, p-value = 0.01148
alternative hypothesis:	true location difference is not equal to c(0,0)

Figure 3. Hotelling T^2 Test Output

Based on Figure 3, the p-value is 0.01 ($< \alpha = 0.05$), which means that H_0 is rejected. Therefore, it can be concluded that there is an effect of learning methods on students' mathematical reasoning and computational thinking abilities.

2. Hypothesis Test 2: The Effectiveness of Learning Methods on Computational Thinking

Next, a t-test was conducted to compare computational thinking abilities between the control class and the experimental class. The results of the test are presented in Figure 4.

```
Two Sample t-test
data: Data_Uji_T_CT$`Computational Thinking` by Data_Uji_T_CT$Perlakuan
t = 1.1562, df = 56, p-value = 0.2525
alternative hypothesis: true difference in means between group 1 and group 2 is not
equal to 0
95 percent confidence interval:
-2.408936  8.985217
sample estimates:
mean in group 1 mean in group 2
85.41374      82.12560
```

Figure 4. T-Test Results for Computational Thinking Ability

Based on Figure 4, the p-value is 0.2525 ($> \alpha = 0.05$), indicating that H_0 is accepted. Therefore, it can be concluded that the context-based PISA principle learning method is not significantly effective in improving students' computational thinking abilities.

3. Hypothesis Test 3: The Effectiveness of Learning Methods on Mathematical Reasoning

The t-test was also conducted for mathematical reasoning ability, with the results shown in Figure 5.

```
Two Sample t-test
data: Data_Uji_T_PM$`Penalaran Matematis` by Data_Uji_T_PM$Perlakuan
t = 2.5084, df = 56, p-value = 0.01505
alternative hypothesis: true difference in means between group 1 and group 2 is not
equal to 0
95 percent confidence interval:
1.376229 12.291632
sample estimates:
mean in group 1 mean in group 2
83.87097      77.03704
```

Figure 5. T-Test Results for Mathematical Reasoning Ability

Based on Figure 5, the p-value is 0.01 ($< \alpha = 0.05$), indicating that H_0 is rejected. Thus, it can be concluded that the context-based PISA principle learning method is effective in improving students' mathematical reasoning abilities.

Discussion

The results of this study reveal several important findings regarding the application of context-based PISA principles in mathematics learning and their impact on students' computational thinking and mathematical reasoning abilities. The following discussion provides an in-depth analysis of these findings, focusing on the three main aspects that constitute the core of this study

The Effect of Learning Methods on Students' Computational Thinking and Mathematical Reasoning Abilities

The results of the multivariate analysis using Hotelling's T^2 test revealed a significant effect of the context-based PISA principles on students' mathematical reasoning and computational thinking abilities simultaneously ($p = 0.02 < 0.05$). This finding supports the hypothesis that a contextual learning approach aligned with PISA principles can effectively enhance both abilities as an integrated unit of mathematical competence.

These results are consistent with the findings of [Csapó & Molnár \(2019\)](#), who emphasized that contextual learning can stimulate higher-order thinking skills simultaneously. The concurrent development of both abilities suggests a cognitive connection between mathematical reasoning and computational thinking, as stated by [Lockwood et al., \(2022\)](#), who argued that both share a common epistemological foundation rooted in logical and systematic thinking.

Further support comes from recent research by [Benton et al., \(2016\)](#), which demonstrated that contextual, problem-based learning environments foster the development of complex cognitive processes, including mathematical reasoning and computational thinking. Their findings indicate that when students engage with relevant contextual problems, multiple cognitive pathways are activated in parallel, reinforcing both capabilities.

[Gravemeijer et al., \(2017\)](#), in a longitudinal study, highlighted that contextual learning emphasizing real-world relevance as embraced by PISA facilitates the development of integrated mathematical competencies. This aligns with [Wing \(2006\)](#) assertion that computational thinking is inherently linked to mathematical reasoning, particularly in addressing complex problems.

Comparative study of educational practices across European countries, identified a positive correlation between the adoption of PISA principles and improvements in students' multidimensional cognitive skills. Their findings underscore that focusing on contextual problems can simultaneously activate diverse cognitive domains, including reasoning and computational thinking.

This simultaneous enhancement is further validated by [Schoenfeld \(2016\)](#) research, which emphasized that authentic and contextual learning experiences provide optimal conditions for cultivating integrated mathematical skills required in the 21st century. The interrelationship between mathematical reasoning and computational thinking is strengthened through instructional approaches that prioritize solving real-world problems, as advocated in the PISA framework.

Effectiveness of Learning with Contextual-Based PISA Method Reviewed from Computational Thinking Ability

In contrast to computational thinking, the results of the univariate analysis showed that the application of contextual-based PISA principles was effective in significantly improving students' mathematical reasoning abilities ($p = 0.01 < 0.05$). This finding indicates that a learning approach that adopts PISA principles with an emphasis on meaningful and relevant contexts has a strong positive impact on the development of mathematical reasoning abilities.

These results are consistent with the research of [Mercier & Sperber \(2017\)](#), who emphasized that mathematical reasoning develops optimally when students are engaged in a meaningful learning context that is relevant to real-world experiences. They found that contextual learning provides a conducive environment for developing students' abilities to draw logical conclusions and construct valid mathematical arguments.

These findings also support the arguments put forward by [Brodie et al., \(2010\)](#) and [Mata-Pereira & da Ponte \(2017\)](#), who noted that mathematical reasoning grows through the process of asking and answering critical questions about mathematical truths in a meaningful context. The context-based PISA principles appear to effectively create a learning environment that encourages students to engage with these questions, thereby strengthening their reasoning skills.

[Reid & Knipping \(2021\)](#), in their recent study, found that a learning approach emphasizing the application of mathematics in real-world contexts such as the one proposed by the PISA principles significantly improves students' ability to construct and justify mathematical arguments. This result aligns with the mathematical reasoning indicators proposed by [Sumarmo \(2018\)](#) and [Stylianides \(2016\)](#), highlighting the importance of authentic mathematical practice in promoting deeper reasoning abilities.

A comparative study by [Thompson et al., \(2017\)](#) across various OECD countries also showed that a learning approach aligned with the PISA principles consistently resulted in improvements in students' quantitative reasoning abilities, particularly in non-routine situations. Their research identified that contextualizing mathematical problems helped students transfer their

knowledge and reasoning skills to new, unfamiliar contexts, demonstrating the transferability of learning through contextualized teaching.

Herbert et al., (2019) in their longitudinal study found that sustained exposure to contextual mathematical problems led to significant improvements in students' logical argumentation and mathematical justification abilities. They emphasize that authentic learning experiences such as those promoted by the PISA principles play a crucial role in developing robust mathematical reasoning skills.

Recent research by Lithner (2017) further reinforces these findings, showing that contextual problem-based learning aligned with PISA principles fosters optimal conditions for the development of mathematical creative reasoning. This component of reasoning is critical to overall mathematical thinking, as it allows students to employ flexible and adaptive strategies to solve complex problems.

Zulnaidi et al., (2020) in their international study, identified that learning that emphasizes authentic contexts successfully helped students overcome difficulties in developing both deductive and inductive reasoning in mathematics. They emphasized that context-based PISA principles assist students in making connections between abstract mathematical concepts and real-world applications, which is a key factor in developing effective mathematical reasoning.

Effectiveness of Contextual-Based PISA Learning in Terms of Mathematical Reasoning Ability

The results of the univariate analysis using the t-test indicated that the application of contextual-based PISA principles was less effective in enhancing students' computational thinking abilities ($p = 0.25 > 0.05$). Although there was an increase in the average score in the experimental group, the improvement did not reach statistically significant levels. This finding raises important questions regarding the factors that influence the development of computational thinking within the context of mathematics learning.

These results align with the research of Kalelioglu et al., (2019), who found that the development of computational thinking requires a more specific and structured pedagogical approach than the general contextual approach. Their study highlighted that computational thinking necessitates explicit scaffolding and repeated practice, elements that may not have been optimally incorporated into the implementation of the context-based PISA principles in this study.

Weintrop et al., (2016) also emphasized that computational thinking has unique characteristics that require a more technical and algorithmic approach. They suggest that the development of computational thinking should combine contextual learning with structured practice, focusing on specific components such as decomposition, pattern recognition, abstraction, and algorithms, as identified by Supiarmo et al., (2021) in their research.

Computational thinking takes longer to develop compared to conventional mathematical skills. They proposed that pedagogical interventions aimed at improving computational thinking should ideally be carried out over a longer period with higher intensity. This longer timeline could be a limitation of the current study's design.

The findings also reflect those reported by Azizah et al., (2022), who noted that students' computational thinking abilities remain relatively low, especially in areas such as pattern recognition, information analysis, abstraction, and algorithms. This indicates that the challenges in fostering computational thinking are multifaceted and demand a more comprehensive and sustainable pedagogical approach.

Additionally, Sentence & Csizmadia (2017), in their longitudinal study across several European countries, identified that effective development of computational thinking requires a pedagogical approach that extends beyond contextual learning alone. They emphasize the importance of integrating explicit instruction with contextual problem-based learning to achieve optimal results.

Roman-Gonzalez et al., (2018) also Socio-economic factors and access to technology play a significant role in the development of computational thinking. These factors, which may have acted as uncontrolled intervening variables in this study, highlight the need to account for such contextual influences when designing future pedagogical interventions aimed at improving computational thinking.

CONCLUSION

Based on the results of the research and analysis that have been conducted, it is concluded that there is an influence between the contextual PISA principle-based learning method and conventional learning on students' mathematical reasoning and computational thinking abilities. The PISA principle-based learning method has proven effective in improving students' mathematical reasoning abilities, but has not shown optimal effectiveness in improving computational thinking abilities..

Teachers can use the contextual PISA principle-based learning approach as an alternative in developing students' mathematical reasoning abilities. This approach has the potential to be applied to the development of various other competencies in different mathematical materials, which makes it a valuable reference for further research.

This study has several limitations that need to be considered. The implementation carried out in a limited time may not be enough to develop computational thinking skills in depth. The scope of the study only covers one school with certain characteristics, so the results cannot be generalized widely. In addition, the limited scope of material and instruments that are still in the development stage can affect the accuracy of the measurement. External factors such as family support and access to technology outside of learning are also not fully controllable, which may have had an impact on the outcomes.

For future research, it is recommended to explore the impact of the contextual PISA principle-based learning approach over a longer period, as this may lead to a deeper development of computational thinking skills. Additionally, broadening the scope of the study to include more schools with diverse student populations could provide a more comprehensive understanding of the method's effectiveness. Integrating more specific and structured exercises focusing on computational thinking, as well as addressing the external factors affecting student learning, could further optimize the effectiveness of this learning approach.

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