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Computational thinking ability becomes a predictor of mathematical critical thinking ability

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***Abstract*:**
This research aims to determine the relationship between computational thinking ability and mathematical critical thinking ability of seventh-grade students at SMPN 49 Jakarta. Computational thinking ability is skills or processes in solving problems effectively, while mathematical critical thinking ability is a process of analyzing problems to make an accurate decision. This research used correlation research with research subjects consisting of 14 female students and 16 male students. The instrument in this study is a test in the form of a description, which is measured using indicators. This study used decomposition, pattern recognition, abstraction, and algorithm thinking as indicators of computational thinking ability. This study uses elementary clarification, essential support, inference, advanced clarification, strategy, and tactics as indicators of mathematical critical thinking. The outcome of this research showed a positive correlation between computational thinking ability and students' mathematical critical thinking ability. The relationship analysis shows a simultaneous and significant relationship between computational thinking and essential mathematical thinking abilities. The correlation test results using Pearson Product Moment obtained a result of 0.897 with a coefficient of determination of 80.5%. The magnitude of the correlation indicates that the two abilities have a solid relationship. If computational thinking ability is high, then mathematical critical thinking ability is also high, and if computational thinking ability is low, then mathematical critical thinking ability is also low.

Keywords: Computational Thinking; Critical Thinking; Mathematical Thinking; Problem-Solving; Thinking Ability.

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Introduction

Students are required to acquire abilities that assist the technologies in this period of technological advancement. The abilities that can face technological developments are the ability to think computationally and critically mathematically. It is evidenced by adding the computational thinking category to the Programme for International Student Assessment (PISA) 2021 (Kusaka, 2021). In addition, the Indonesian Minister of

Education, Culture, Research, and Technology has also designed a new policy on the Indonesian curriculum for 2022 by including computational thinking in it (Apriani et al., 2021). The World Economic Forum said critical thinking is an ability that ranks at the top of the list of must-have abilities in the next five years. Students need these abilities because they are useful for training students in logical, critical, and systematic thinking (Yasinta et al., 2020).

Mauliani (2020) said in his research that computational thinking is related to mathematical critical thinking abilities. It is possible to acquire computational thinking skills if we first grasp the fundamentals of mathematics. Additionally, both capabilities share the same thought process in solving problems by steps that are not only precise but also accurate. In particular, computational thinking can be one of many methods to solve all the discipline's issues, like mathematics (Yuntawati et al., 2021). There are several implementations of computational thinking, one of them is algebra material. Research reinforced this implementation by Cahdriyana and Richardo (2020), states that students will be allowed to implement computational thinking while solving problems in algebra material. In contrast, Fridanianti, Purwati, and Murtianto (2018) said that critical thinking skills have a more substantial relation with algebra material than computational thinking skills.

Wibiwo and Faizah (2021) stated that when solving questions in Algebra, it is crucial to pay attention to the reason behind the answer. Algebra is a mathematics subject taught at the seventh-grade junior high school level. The introduction of algebraic material begins with linear equations and inequalities of one variable (Badawi et al., 2016). Additionally demonstrated is the connection between computational thinking abilities and mathematics by a statement from Wing (2006) that computational thinking is bound to solve problems. In addition, according to Ziarati et al. (2022), mathematical critical thinking is a method used to solve mathematical problems. Although the two abilities have almost the same pattern, according to Setyautami (2020), the two abilities have differences in which the computational thinking ability develops a sequence of steps toward an appropriate solution while the mathematical critical thinking ability takes the process of analyzing mathematical problems in depth to find appropriate problem-solving.

Research by Nuvitalia et al. (2022) in ninth-grade students showed that the level of students' mathematical critical thinking ability was in the medium category with a presentation of abstraction of 56.19%, generalization of 58.73%, pattern recognition of 46.03%, decomposition of 53.24%, and algorithms of 51.74%. In addition, research conducted by Paf and Dincer (2021) found that students' computational thinking skills had a favourable and concrete relationship to creative problem-solving abilities. John Lemay et al. (2021) confirmed that using algorithmic and critical creative, problem-solving, and cooperative thinking could foster the development of computational thinking ability. Then, there is research by Noor and Ranti (2019) that says that essential mathematical thought skills are related to computational thinking abilities that affect junior high school mathematics learning. Meanwhile, research by Mubarokah et al. (2023) about students' deep computational thinking abilities solving AKM numeracy-type material number pattern questions from work on the number pattern test questions that have been give to 25 students class VIII G SMP Nuris Jember shows that there were four students (16%) who had low computational thinking skills, there were 16 students (64%) who had moderate computational thinking skills, and there were five students (20%) who had low computational thinking skills. In other words, the level of computational thinking ability at class VIII G SMP Nuris Jember is moderate.

Based on relevant research above, some studies connect mathematical ability with computational thinking ability. However, no research has explicitly discussed the connection between junior high school students' computational and mathematical critical thinking abilities. Therefore, the researcher conducted a study using algebraic material to know the relationship between computational thinking ability and students' mathematical critical thinking ability at SMPN 49 Jakarta.

Research Methods

This research belongs to the correlation research category, which aims to determine the relationship between students' mathematical critical thinking skills and computational thinking skills without first giving students treatment. The location of this research is SMP Negeri 49 Jakarta. The population of this study was all class VII of SMP Negeri 49 Jakarta, totalling 323 students, with a sample of 30 students of class VII E, 14 of whom were female and 16 of whom were male, used in this study. In this study, the sampling technique employed was cluster random sampling.

This study used a particular instrument to measure computational and mathematical critical thinking ability. Decomposition, pattern recognition, abstraction, and thinking algorithms are the indicators of computational thinking ability (Fajri et al., 2019) used in the five descriptions that make up the test. Meanwhile, the ability to think critically mathematically is measured by answering seven questions as an explanation. These questions contain indicators from Ennis in Silitonga et al. (2022), namely elementary clarification (making basic clarification), basic support (making fundamental decisions), inference (making conclusions), advanced clarification (producing progressive clarification), and strategies and tactics. The essay test questions are first used for lecturers, teachers, and students through validity and reliability assessments. With a total of 1 lecturer, one teacher, and 32 students, the results of the validity and reliability tests which have been done to the students are presented and explained further. The results of the validity test that was carried out in this study are shown in the following Table 1.

Table 1. Results of Testing for The Validity of Computational Thinking Ability Instruments

Item Number	r_{count}	r_{table}	Description
1	0,707	0,349	Valid
2	0,458	0,349	Valid
3	0,752	0,349	Valid
4	0,712	0,349	Valid
5	0,800	0,349	Valid

Based on Table 1, testing for the validity of the computational thinking ability produces all valid test instruments because they meet the requirements, namely r_{count}> r_{table}. Table 2 below displays the outcomes of the mathematical critical thinking skills validity test.

Table 2. Results of Testing for The Validity of Mathematical Critical Thinking Ability Instruments

Item Number	r_{count}	r_{table}	Description
1	0,413	0,349	Valid
2	0,612	0,349	Valid
3	0,459	0,349	Valid
4	0,550	0,349	Valid
5	0,738	0,349	Valid
6	0,708	0,349	Valid
7	0,539	0,349	Valid

Based on Table 2, the validity test of mathematical critical thinking skills produces all valid test instruments because they meet the requirements, namely $r_{count}>r_{table}$. The table below shows the reliability test results in this study with the conditions: if the value $r_{11}>0.6$, then the question instrument can be reliable.

Table 3. Computational Thinking Ability Instrument Reliability Test Results

r_{11}	N question
0,70	5

Based on the testing results, the reliability of the ability to instrument computational thinking above the value was 0.70 > 0.6. It means that the instrument of computational thinking ability is confirmed reliable. It means that the instrument of computational thinking ability is declared trustworthy. Meanwhile, the results of the reliability test of the mathematical critical thinking ability instrument are shown in Table 4 below.

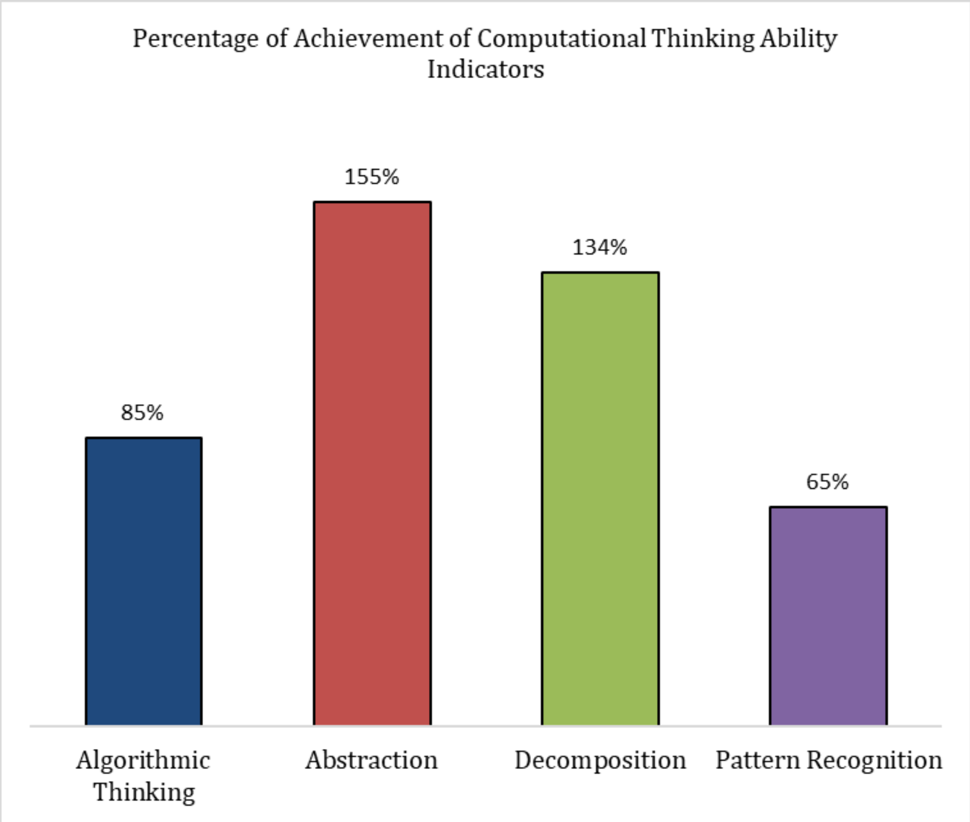
Table 4. Mathematical Critical Thinking Ability Instrument Reliability Test Results

r_{11}	N question
0,65	7

Based on the testing findings, the mathematical critical thinking ability instrument was trustworthy, with a reliability coefficient above 0.70>0.6. The legitimacy test came about, stating that all test instruments are legitimate. In contrast, the reliability test scored highly on the ability to think computationally and moderately on the ability to think mathematically critically. The data generated for this research were processed using Microsoft Excel and SPSS 25 for Windows. The linearity test and the normality test were the prerequisite tests performed. Shapiro-Wilk and ANOVA were used to test normality and linearity. Meanwhile, the Pearson Product Moment correlation test determines the link between these two talents.

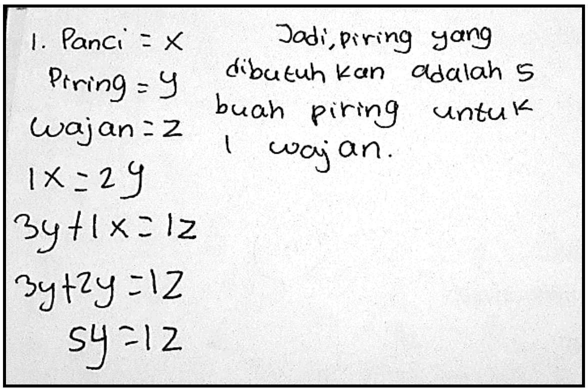
Results and Discussions

Computational thinking skills (X) and mathematical critical thinking skills (Y) are the findings of this study taken from test results tested on 26 students of class VII E based on the instruments of the two variables. The data collection following the test on the signs for attaining these two skills. According to Fajri et al. (2019), indicators of computational thinking skills include algorithmic thinking, abstraction, decomposition, and pattern recognition. The following represents the percentage findings for the markers of computational thinking abilities.



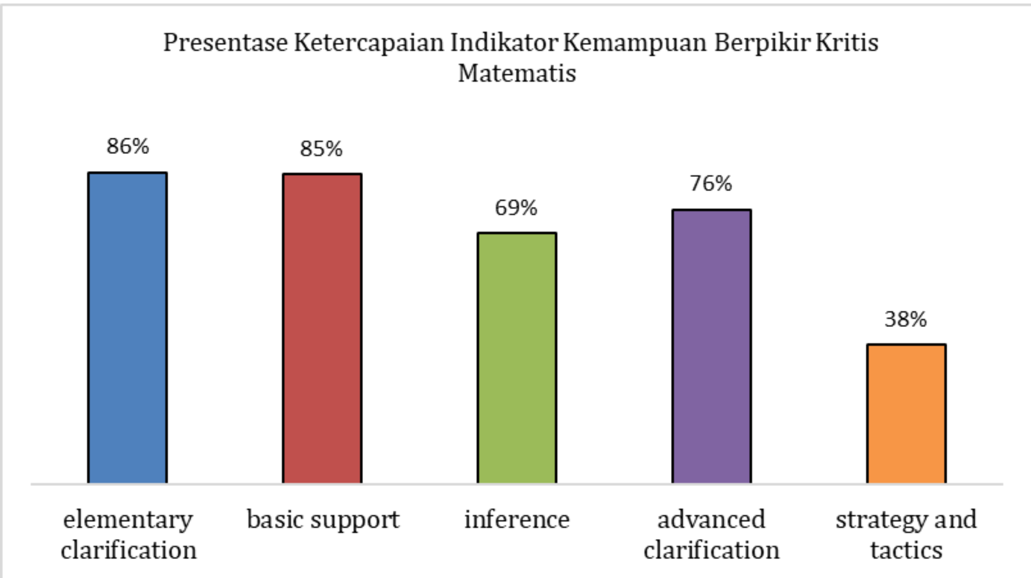
Picture 1. Percentage of Achievement of Computational Thinking Ability Indicators

The picture above shows that the abstraction indicator reached 155%, becoming the highest percentage among the other indicators. It aligns with a previous study conducted by Muslimawati et al. (2023), which revealed the same results, reaching a value of 96%. These results indicated that students could generalize and identify the common elements that created patterns. An example shown in Picture 2 proved that students wrote descriptional questions in mathematical equations. Therefore, Maharani (2020) assured that abstraction is the process of creating a simple form from a complex form by eliminating irrelevant things, finding relevant patterns, and separating ideas or ideas from natural things.



Picture 2. Results of Student Answers

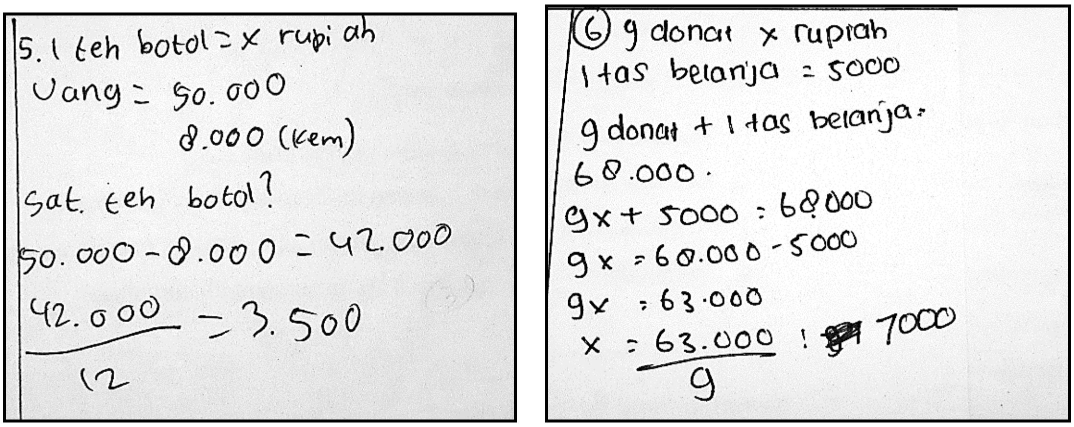
Furthermore, the decomposition indicator has the second highest percentage, 134%. These results indicated that students split the complex data to be more manageable and understandable, under Angeli et al. (2016), who defined decomposition as the ability to break down a problem into simpler parts and answer the problem. The algorithm thinking indicator positioned at the third highest percentage, reaching 85%. Students demonstrated high-level problem-solving abilities by compiling steps to tackle the same difficulties. According to Nuvitalia et al. (2022), thinking algorithms write automated solutions through algorithmic thinking or sequential steps. The last percentage achieved by the pattern recognition indicator reached 65%. This result aligns with a study by Sari et al. (2023), which marked that pattern recognition became the minor indicator by gaining only 25%. It indicates that students are capable enough to see similarities and differences in the information provided so that they can find patterns in solving problems. Pratama et al. (2023) define pattern recognition as observing or analyzing various similarities between difficulties.



Picture 3. Percentage of Achievement of Mathematical Critical Thinking Ability Indicators

Meanwhile, for indicators of mathematical critical thinking skills, this study uses indicators according to Ennis in Oktavia (2020), namely elementary clarification (conducting basic clarifications), basic support (making basic decisions), inference (making conclusions), advanced clarification (producing further clarifications)), strategy and tactics (devise strategy and tactics). Based on the research findings, the accomplishment data for each indicator is shown in Picture 3.

The elementary clarification indicator has a percentage of 86%. This indicator is similar to the research result of Ilhamsyah et al. (2021), which became the indicator with the highest rate, reaching 69%. It shows that pupils can articulate what is understood and what is requested. Picture 4 demonstrates how students are asked the description questions and are required to write down what they know. Rahmaton (2018) described elementary clarification as the ability to understand, explain and give meaning to data and information in easy-to-understand terms.



Picture 4. Results of Student Answers

Then, the essential support indicator gained a percentage of 85%; this indicated that students determined the formula correctly from the questions given. The primary support indicator is students' basic skills in adjusting information from sources, observing, and considering the results (Magdalena & Muslim, 2023). Furthermore, the advanced clarification indicator had reached a percentage of 76%. It implied that students solved problems using the definitions mentioned in the questions. Silitonga et al. (2022) validated that advanced clarification consists of identifying terms, considering reports and identifying assumptions. The next indicator, namely inference, had a percentage of 69%. It proved that students' students base their conclusions on the information they learn from their replies and findings.

Moreover, according to Ennis in Magdalena and Muslim (2023), strategy and tactics indicators are students' skills in deducing and inducing information to make decisions from the results considered. Strategy and tactics indicators had the lowest percentage of 38%. These findings strengthen the research results obtained by Prastyo and Dimas (2023), who noticed that strategy and tactics indicators also hit the lowest rate of 42.6% compared to other indicators. It pointed out that students determined the strategies used in solving problems. Silitonga et al. (2022) further explained that strategy and tactics involve determining an action and interacting with others.

Furthermore, to get a description of the data, computations are made. Data obtained from the test results show that computational thinking ability has a standard deviation of 19.006 and an average value of 75,038. Meanwhile, mathematical critical thinking ability has a standard deviation of 18.657 and an average value of 73.615.

Table 5. Data Description Results

		Computational Thinking	Mathematical Critical Thinking
N	Valid	26	26
	Missing	0	0
Mean		75.038	73,615
Median		70.000	71,000
Std. Deviation		19.006	18,657

Moreover, tests for information's ordinariness served to do the necessary testing. Table 6 displays the normality test's results at the α level used (this study used an α level of 5%). The huge worth of the computational thinking variable is 0.055>0.05, and the mathematical critical thinking ability variable has a consequence of 0.066>0.05. It is reasonable to assume that the final data has a normal distribution.

Table 6. Normality Test Results

	Shapiro-Wilk		
	Statistic	df	Sig.
Computational Thinking	0,924	26	0,055
Mathematical Critical Thinking	0,927	26	0,066

Because the resulting data is normally distributed, the research can be continued by conducting a linearity test. As seen from the calculation result of the linearity test, the Sig is known. Deviation From linearity of 0.445>0.05, where 5% is the α level used in this study. It is possible to conclude that the ability for mathematical critical thinking and computational thinking are directly connected.

Table 7. Correlation Test Results

		Computational Thinking	Mathematical Critical Thinking
Computational Thinking	Pearson Correlation	1	0.847**
	Sig. (2-tailed)		0.000
	N	26	26
Mathematical Critical Thinking	Pearson Correlation	0.847**	1
	Sig. (2-tailed)	0.000	
	N	26	26

After completing the prerequisite tests, conduct a correlation test using Pearson Product Moment at the α level of 5%. Look at the outcome of the correlation test in Table 7. Based on the significant value of Sig. (2-tailed) the significance value of 0.000<0.05 and the value of r_{count} (Pearson Correlation) 0.847>r_{table} 0.388, it is possible to conclude that the ability for mathematical critical thinking and computational thinking are significantly linked.

H_0 explains that there is no relationship or influence between computational thinking abilities (X) and students' mathematical critical thinking abilities (Y), while H_a Explains that there is a relationship between computational thinking abilities (X) and students' mathematical critical thinking abilities (Y). The outcome of testing the research hypothesis with the correlation test showed that the resulting significant value is 0.000 < 0.05. The significant value obtained results in H_0 rejected or accepted H_a. This means that computational thinking ability significantly correlates to the student's mathematical critical thinking ability.

The T-test and the F-test are also used to calculate the significance test. The T-test aims to determine whether or not there is a significant difference between computational thinking skills and mathematical critical thinking skills, and the F-test aims to determine whether there is a simultaneous ability between computational thinking and mathematical critical thinking skills. After calculating the significance test, there is a table of coefficients that shows the results of the T-test, which got a worth of 7.797 with an importance cost of 0.000; one might say that the ability for computational thinking significantly impacts mathematical critical thinking. Meanwhile, the ANOVA table shows that the F-test obtained a value of 60.797 with a significance value of 0.000; one might say that the ability for computational thinking ability has a simultaneous impact on mathematical critical thinking. According to Ningsih (2016), the independent variable (X) affects the dependent variable (Y) simultaneously.

Table 4 shows that the R Square value is 0.805, indicating a correlation of 80.5% between computational and mathematical critical thinking skills. The two abilities have a positive correlation, as seen from the correlation coefficient value of 0.897. If computational thinking ability is high, so is mathematical critical thinking ability. Then, if computational thinking ability is low, mathematical critical thinking ability is too. The correlation value obtained is 0.897, indicating the strong relationship between computational thinking ability and students' mathematical critical thinking ability. There is a coefficient of determination of 0.805, which means that computational thinking ability affects 80.5% of the ability to think critically and mathematically. Meanwhile, the remaining 19.5% is impacted by other elements.

Table 4. Coefficient of Determination

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.847[a]	0.717	0.705	10.130

Mauliani (2020) specified computational thinking as a learning scheme with a comprehensive application area in implementing a problem-solving approach. Students with excellent computational thinking skills can solve problems logically, structurally, and systematically (Angraini et al., 2022). It can solve each problem in several practical and efficient steps (Inganah et al., 2023). Students who can solve a problem logically, structurally, and systematically are students who have problem-solving skills. Furthermore, Zuhair (2021) affirmed that computational reasoning skills augmented the critical thinking process.

Additionally, Lisnawita et al. (2021) research stated that computational thinking could raise one's capacity for problem-solving by 84.73%. Figuring out the problem, devising a solution, executing the plan, and re-evaluating the implemented solution are all components of problem-solving ability. Hartanti (2019) states all those components are essential for critical and mathematical thinking. Yasin et al. (2020) claimed that mathematical critical thinking ability is a mathematical thinking method that requires students to comprehend and analyze abstract concepts accurately. Students who master the mathematical essential thinking skills will get used to researching, processing, and explaining basic information correctly before deciding (Karakoc, 2016). Because the structure of mathematical concepts is usually logical and systematic, starting with the most straightforward concept and working their way up to the most difficult one, critical thinking skills in mathematics are required to understand them (Purwanto et al., 2020). Meanwhile, according to Zuhair (2021), with computational thinking skills, students can model mathematical concepts dynamically. It demonstrates the connection between computational and mathematical critical thinking skills.

According to Fajri et al. (2019), indicators of computational thinking ability include decomposition, pattern recognition, abstraction, and algorithmic thinking. The decomposition indicator is the ability to change information to be more easily understood in line with the elementary clarification mathematical critical thinking ability indicator, where students can clarify fundamentally (Silitonga et al., 2022). The pattern recognition indicator is the ability to formulate equations or patterns of existing problems to apply to various issues. The abstraction indicator is the ability to develop a plan to resolve complex problems effectively. These findings were agreed upon by Makhmudah (2018), who said that mathematical critical thinking is a way to differentiate between needed and unnecessary information. The research by Fauzi & Abidin (2019) showed that the stages of mathematical critical thinking skills used by students are figuring out the problem, developing a plan to resolve the issue, solving the problem, and rechecking the results that have worked on. Algorithmic thinking indicators include the ability to solve problems gradually with a plan carried out. In research, Farida (2022) showed that phased implementations of mathematical critical thinking patterns are carried out in stages. From the explanation above, there is a connection between indicators of computational thinking ability and mathematical critical thinking ability.

Because of the numerous similarities between the two abilities, there is a strong correlation between computational thinking and mathematical critical thinking ability. Some similarities are: (1) Computational and mathematical critical thinking abilities use logic. Danindra and Masriyah (2020) research showed that the solution pattern needs logical steps to indicate computational thinking ability, namely algorithmic thinking. Meanwhile, Hartanti (2019) said that mathematical critical thinking is a way of thinking that makes use of logic to make, analyze, evaluate, and make decisions correctly; (2) Both abilities involve abstract thinking. Abstract thinking ability is the fundamental component of computational thinking (Wing, 2010). Meanwhile, according to Firdaus & Rustina (2019), mathematics has abstract concepts that require students to get the skill to think critically, logically, and systematically; and (3) There is a strong connection between the two abilities and mathematics lessons. According to Diantary and Akbar

(2022), implementing computational thinking into mathematics lessons can improve school computational thinking skills. Meanwhile, Kurniawati and Ekayanti (2020) states that critical thinking and mathematics are inseparable.

The existence of a positive correlation between the ability to think mathematics critically and computationally is relevant to the outcome of research by ünveren Bilgiç et al. (2021) that computational thinking ability directly and significantly impacts mathematical critical thinking ability at 84% of pedagogical students' lifelong learning tendencies on computational thinking and critical thinking abilities. The study's outcome is not very different from the outcome of this study. So, in parallel with the opinion of Memolo (2022) that computational thinking-based mathematics instruction requires both creative and critical thinking ability, which is consistent with Mauliani (2020) view that computational thinking ability cannot separated from mathematical critical thinking ability. Dores et al. (2020) said that giving students evaluations can improve their mathematical essential thinking abilities. The review is an essay or description question which helps stimulate students to solve problems. Students' mathematical thinking skills can improve by applying computational thinking (Kawuri et al., 2019). Therefore, test instruments must appraise pupils' computational and mathematical critical thinking abilities (Sa'diyyah et al., 2021). Introducing the students to computational thinking allows them to think critically to help them solve complex problems effectively and efficiently (Lestari & Annizar, 2020).

In addition to mathematical critical thinking ability, computational thinking ability also relates to other mathematical thinking abilities. Research directed by Syarifuddin et al. (2019) concluded that computational thinking ability can improve problem-solving ability by 58.7%, structured thinking ability by 62.6%, critical thinking ability by 58.3%, and logical thinking ability by 57.8% with an average of 59.35%. As per the discoveries of this study, computational thinking ability correlates with problem-solving, structured thinking, critical thinking, and logical thinking abilities. In addition, the research results by Nasiba (2022) showed that problem-solving and creative thinking skills can be improved by conducting primary education based on computational thinking. Based on these studies, it is possible to conclude that mathematical abilities, such as problem-solving, structured thinking, critical thinking, logical thinking, and creative thinking, are also linked to computational thinking abilities.

Conclusions and Suggestions

The findings demonstrated a positive correlation between the computational and mathematical critical thinking skills of SMPN 49 Jakarta students. The Pearson Product Moment correlation test outcome obtained a Pearson Correlation value of 0.897. In addition, computational thinking ability has a significant and simultaneous effect on mathematical critical thinking ability, as indicated by the outcome of the significance test and regression coefficient test. Based on the coefficient of determination, computational thinking ability and mathematical critical thinking ability influence 80.5%. It is hoped that the results of this research can be a further reference for educators or future researchers who desire to explore students' computational thinking and mathematical critical thinking skills. As a result, it is essential to develop learning that can improve computational thinking and mathematical critical thinking ability. For additional research, it is hoped to be a source of information associated with computational and mathematical critical thinking. In addition, future researchers also hope to conduct further research on the profile of mathematical critical thinking ability at the secondary school level because these abilities are abilities that students need to face in the 21st century. The correlation between computational thinking ability and other mathematical abilities must be investigated further and thoroughly in future research.

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