p-ISSN: 2086-4280
e-ISSN: 2527-8827

Integrating Computational Thinking in STEM Learning: An Effort to Improve Students' Problem-Solving Skills

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Article received: 02-11-2023, revised: 13-12-2023, published: 30-01-2024

Abstrak

Perkembangan teknologi yang sangat cepat memaksa seseorang untuk memiliki kemampuan *computational thinking* agar dapat menyelesaikan berbagai permasalahan secara komputasi. Tujuan penelitian ini adalah untuk mendeskripsikan bagaimana implementasi pembelajaran STEM terintegrasi *computational thinking* dalam meningkatkan kemampuan pemecahan masalah siswa. Metode penelitian yang digunakan dalam penelitian ini adalah metode pra eksperimen dengan *one group pretest-posttest design*. Sampel penelitian terdiri dari 21 siswa kelas VIIA SMP Bumi Cendekia Yogyakarta. Instrumen penelitian berupa tes tulis dan lembar observasi. Data penelitian dianalisis dengan menggunakan uji Wilcoxon dan N-Gain. Hasil penelitian ini menunjukkan bahwa persentase keterlaksanaan pembelajaran STEM terintegrasi *computational thinking* mencapai 88% atau dalam kategori baik. Sementara hasil uji Wilcoxon rata-rata kemampuan pemecahan masalah siswa diperoleh nilai signifikansi sebesar 0,000, dengan rata-rata skor N-Gain kemampuan pemecahan masalah siswa sebesar 0,54. Dengan demikian, dapat disimpulkan bahwa implementasi pembelajaran STEM terintegrasi *computational thinking* berpengaruh terhadap kemampuan pemecahan masalah siswa.
Kata Kunci: Berpikir Komputasi; Kemampuan Pemecahan Masalah; Pembelajaran Matematika; STEM

Abstract

The rapid development of technology forces a person to have computational thinking skills in order to solve various problems computationally. The purpose of this research is to describe how the implementation of STEM learning integrated with computational thinking in improving students' problem-solving skills. The research method used in this research is pre-experimental method with one group pretest-posttest design. The research sample consisted of 21 students of class VIIA Bumi Cendekia Junior High School, Yogyakarta. The research instruments were written tests and observation sheets. The research data were analyzed using Wilcoxon and N-Gain tests. The results of this study showed that the percentage of STEM learning implementation integrated with computational thinking reached 88% or in the good category. While the results of the Wilcoxon test on the average student problem solving ability obtained a significance value of 0.000, with the average N-Gain score of students' problem-solving ability was 0.54. Thus, it can be concluded that the implementation of STEM learning integrated with computational thinking affects students' problem-solving skills.
Keywords: Computational Thinking; Problem-Solving Skills; Mathematics Learning; STEM

I. INTRODUCTION

The rapid development of technology in the 21st century forces a person to have at least 4C skills, namely critical thinking, creativity, collaboration, and communication. In fact, Grover (2018) and Riddell (2018) mentioned that someone also needs to have computational thinking skills as a complement to the existing 4Cs. In addition, the Indonesian government through the Permendikbud also announced that computational thinking is one of the Basic Competencies that need to be taught and learned in the Indonesian curriculum (Zahid et al., 2021) Computational thinking skills are needed to solve certain problems computationally (Abd.Latif et al., 2021).

Computational thinking is a person's ability to face and solve problems using a certain algorithm so that the algorithm can be used effectively to solve similar problems (Wing, 2017). Although experts differ in opinion about this definition of computational thinking. However, they argued that there are at least 4 components used in problem solving that use computational thinking, namely: decomposition, pattern recognition, abstraction, and algorithm (Angeli et al., 2016; V. Barr & Stephenson, 2011; Selby & Woollard, 2013; Wing, 2011).

According to Zahid (2020), computational thinking is one type of thinking skill, so in teaching it there are two ways that can be conducted, namely by opening a special class to discuss the thinking skill or by integrating it in a particular subject (Cotton, 1991). Integration of computational thinking can be conducted into various scientific fields, not only restricted to the computer field. As Barr and Stephenson (2011) mentioned that computational thinking can also be inserted into Mathematics, Science, and even Art subjects. Computational thinking is a synthesis of critical thinking skills and creative thinking skills (Nurwita et al., 2022) so that this will greatly assist students in thinking logically related to problem solving in mathematics learning (Cahdriyana & Richardo, 2020; Pitriyani & Afriansyah, 2023).

One of the learning models that can be combined with computational thinking is STEM (Science, Technology, Engineering, and Mathematics). STEM is a learning approach that combines various disciplines to help students acquire various kinds of knowledge and abilities (Hafni et al., 2020). Stohlmann et al. (2012) said that STEM learning is very important to support student success in the future. It is because STEM learning can encourage students to become problem solvers, innovators, inventors, and logical thinkers (Morrison, 2006). Activities in STEM learning are also needed to solve problems creatively and innovatively through various scientific perspectives (Maharani, 2020).

The integration of computational thinking with the STEM learning model has been studied by Rahman (2022), research that focuses on the integration of computational thinking in the EDP STEM learning model using SimSketch modeling showed the results that the integration of computational thinking with SimSketch modeling can be applied in science learning to boost motivation and interest in learning and students' critical thinking skills. In addition, research handled by Soffa et al. (2023) also showed that the implementation of learning with computational thinking in Natural and Social Science lessons at the elementary school level can also bring out the foundation components of computational thinking, namely decomposition and algorithms. The implementation of the learning also received a positive response from the students. While the literature study that was conducted by Wang (2022) suggested learning implementation that integrates computational thinking and STEM.

Based on the description above, the researchers interested in conducting research in the form of implementation of STEM learning integrated with computational thinking at junior high school level. The purpose of this research was to describe how the implementation of STEM learning integrated with computational thinking and its effect on students' problem-solving skills. This learning is a combination of science and mathematics subjects. The science subject took the material of Heat and its Transfer. Meanwhile, the mathematics subject took the area and perimeter of quadrilaterals and triangles.

II. METHOD

This is pre-experimental research with one group pretest-posttest design. This study consisted of one experimental class and did not use a control class. The research began with giving a pretest, giving treatment in the form of implementing STEM learning integrated with computational thinking, and giving a posttest.

The population of this study were 7th grade students of Bumi Cendekia Junior High School Yogyakarta, totaling 41 students. Sampling was determined using purposive sampling technique due to certain considerations and VIIA class was chosen which amounted to 21 students. The research sample was then divided into 3 groups with each group consisting of 7 students.

This research instrument was a written test that was used to determine students' problem-solving skills and observation sheets was used to measure the implementation of STEM learning integrated with computational thinking. The computational thinking indicators used in this study consist of (1) decomposition, students are able to describe and explain the information contained in the problem given, (2) pattern recognition, students have the capacity to recognize similar and distinctive patterns that are applied to find solutions to problems, (3) abstraction, students are able to make conclusions by ignoring irrelevant elements in problem solving, and (4) algorithm, Students are able to formulate logical steps in solving a problem.

Data analysis on students' pretest-posttest scores was done quantitatively. The pretest value is the value obtained before students are given treatment in the form of implementing STEM learning integrated with computational thinking. Meanwhile, the posttest value is the student value obtained after the students are given the treatment in the form of implementing STEM learning integrated with computational thinking. These values will be analyzed using the Wilcoxon test because the data from the pretest-posttest results of problem-solving skills are not normally distributed. In addition, the data will also be evaluated using the N-Gain score to figure how much the average increase in students' problem-solving ability. The way to calculate the N-Gain score is as follows:

$$N - Gain = \frac{posttest - pretest}{maximum\ score\ - pretest}$$

From the calculation of the average improvement score above, it is then classified into the N-Gain score categories shown in Table 1.

Table 1.
N-Gain Score Category

N-Gain Score	Category
$g > 0{,}7$	High
$0{,}3 < g \leq 0{,}7$	Medium
$g \leq 0{,}3$	Low

III. Result and Discussion

STEM learning activities integrated with computational thinking were carried out in accordance with the plans that have been prepared and observations were made. The observation was conducted by an observer to the teacher who implemented STEM learning integrated computational thinking.

Students were given a problem, "Bumi Cendekia Junior High School wants to distribute food to local residents, but the food distributed is hot food. The school wants the food distributed not to cool down easily. In addition, the food box must also consume a small amount of material for the specified volume". Next, the teacher asked students, "How to make a food box that is able to contain a lot of food with minimal material and is able to withstand heat?" and provided the criteria for a successful solution and its limitations shown in Table 2.

Table 2.
Successful Solution Criteria and Constraints

Criteria for a Successful Solution	Limitations
A container that can fit the specified food using as little material as possible.	Each box design must be able to hold the food provided.
Can retain the heat of the food the longest	Each container contains the same amount of food

Criteria for a Successful Solution	Limitations
	and the temperature is measured after the same period.

To find out whether the STEM learning integrated with computational thinking went well or not, researchers used the learning implementation observation sheet. The result of the observation of the implementation of STEM learning integrated with computational thinking is presented in Table 3.

Table 3.
Implementation of STEM Learning Integrated with Computational Thinking

No	Activities	Score	Description
Opening Activity			
1	Opening the lesson and praying	3	The teacher has opened the lesson well and asked one of the students to pray
2	Condition the class and check student attendance	3	The teacher asks about who is absent
3	Prepare learning resources and learning media	3	The teacher has prepared the items needed for learning
4	Motivating students' learning readiness	2	The teacher has given motivation. However, it is not specific to the material being studied
5	Doing apperception	2	The teacher only asked about the previous meeting material in general
6	Delivering learning objectives	3	The teacher has specifically conveyed the learning objectives to be attained
7	Explaining the learning activity plan	3	The teacher explains in detail the learning plan
Core Activities			
8	Decomposition	3	The teacher instructs each group to determine 3 dimensions of a box with a predetermined volume ($1000 cm^3$), where the same dimension can only be chosen by a maximum of 2 groups. After the dimensions of the box are agreed upon, the teacher distributes Student Worksheet 1. All groups construct the box with the given materials and calculate the surface area.
9	Pattern recognization	2	The teacher asked each group to provide 5 plastic cups, one as a control (without being coated with other materials, and the other 4 cups are coated with plastic, oil paper, aluminum foil, and styrofoam). The prepared cups were filled with hot water (initial temperature measured with a thermometer) then covered and waited for 10 minutes. After 10 minutes, each water in the glass is measured its final temperature and recorded on Student Worksheet 2. At the end of the activity, students are expected to discover that the glass with the smallest temperature drop is the best insulated glass to keep the food

No	Activities	Score	Description
			inside warm.
10	Abstraction	2	The teacher asks the students to discuss an appropriate food box design and put it into sketch form. This plan consists of a drawing of the food box design according to its size and then a timeline for making the food box. Each group makes 2 plans. After completing the design drawings and determining the timeline for making the product, students begin to make the food box product along with the insulator.
11	Algorithm	3	The teacher asks students to test the food packaging boxes repeatedly using clearly formulated success criteria, measurements, and constraints.
Closing Activities			
12	Reinforcing students' opinions	3	The teacher always reinforces students' opinions clearly
13	Classify and provide explanations for students' opinions that are not correct	3	The teacher always clarifies students' opinions that are not correct
14	Giving individual and group assessments	3	The teacher records individual activity and assesses each group well
15	Conducting evaluation	2	The teacher only asks questions to some students.
16	Summarize the learning material	3	The teacher appoints some students to conclude the lesson
17	Conveying the upcoming material	2	The teacher only mentions the chapter in general
18	Closing the lesson with greetings	3	Before the teacher says salam, the teacher asks one of the students to lead the prayer.
Total Score		48	
Maximum Score		54	
Percentage		88%	Good

Adapted from Rahman (2022)

Based on Table 3, teachers have implemented STEM learning integrated with computational thinking very well. This can be viewed from the results of the percentage of learning implementation which reached 88% or fell into the good category.

Data on students' problem-solving skills obtained before and after the implementation of STEM learning integrated with computational thinking are presented descriptively quantitatively based on pretest and posttest scores in Table 4.

Table 4.
Students' Problem-Solving Skills

	Pretest	Posttest
Minimum Score	70	70
Maximum Score	97	100
Mean	76,71	86,86
Std. Deviation	9,660	11,092

p-ISSN: 2086-4280
e-ISSN: 2527-8827

Based on Table 4, the results of the pretest scores obtained a minimum value of 70, a maximum value of 97, and an average of 76.71. While in the results of the posttest value, the minimum value is 70, the maximum value is 100, and the average is 86.86.

Before hypothesis testing is implemented on the research data, a normality test will be carried out on the data from the pretest-posttest results of students' problem-solving skills. The outputs of the normality test of the pretest-posttest results of students' problem-solving skills are presented in Table 5.

Table 5.
Normality Test Results

	Shapiro-Wilk		
	Statistic	df	Sig.
Pretest	0,721	21	0,000
Posttest	0,857	21	0,006

Based on Table 5, the significance value of the pretest results is 0.000, where $0.000 < 0.05$, so it can be inferred that the pretest data is not normally distributed. Meanwhile, the posttest results obtained a significance value of 0.006, where $0.006 < 0.05$, which means that the posttest data is also not normally distributed.

The Wilcoxon test was applied because the pretest-posttest data were not normally distributed. This test was applied to measure the average difference in pretest-posttest results. The Wilcoxon test results are shown in Table 6.

Table 6.
Wilcoxon Test Results

Test Statistics[a]	
	Posttest-Pretest
Z	-3,526[b]
Asymp. Sig. (2-tailed)	0,000

Based on Table 6, the Asymp. Sig. (2-tailed) value of 0.000, where $0.000 < 0.05$, which means that there is a significant difference between the pretest and posttest results of students' problem-solving skills.

To find out how much the average increase in students' problem-solving ability after being given treatment will be evaluated using the N-Gain score. The N-Gain scores on students' problem-solving skills are shown in Table 7 below.

Table 7.
N-Gain Score Results

N-Gain Score	Category	Number of Students
$g > 0{,}7$	High	6
$0{,}3 < g \leq 0{,}7$	Medium	10
$g \leq 0{,}3$	Low	5
Average Score	Medium	0,54

Based on Table 7, there were 6 students who reached an increase in problem solving skills in the high category, 10 students reached an increase in the medium category, and 5 students reached an increase in the low category. While the average score of improving students' problem-solving skills is at 0.54 and is included in the moderate category.

Based on the results presented above, teachers have implemented STEM learning integrated with computational thinking well as evidenced by the percentage of learning implementation that reached 88%. Although the learning has been well implemented, there are still some obstacles in its implementation, especially in the aspect of computational thinking.

Students, in the decomposition process, still have difficulty in determining the 3-dimensional box with a volume of 1000 cm^3. In addition, in order to use less material, students need to pay attention to the surface area. Students are able to determine the 3 dimensions of the box, but the volume tends to be very small and not close to the specified volume. Furthermore, some students also still have difficulty in connecting volume and surface area. This will affect the design that will be produced. The small volume will result in the food not being able to fit in the container. Therefore, the role of the teacher is needed to assist students find the ideal size.

Figure 1. Students write down the size of the food container

Obstacles were also found in the pattern recognition process, in this process students were asked to record any changes that occurred in the water temperature in each place. However, some students still have difficulty in using a temperature measuring device. This resulted in the recording of temperature changes being less accurate.

Figure 2. Students measuring water temperature

Furthermore, students, in the abstraction process, succeeded in developing a problem-solving plan in the form of a product sketch that was in accordance with the specified criteria. Students were also able to make products well. However, the products produced tended to be the same between groups. Some students also still had difficulty in identifying the weaknesses and strengths of their designs. This was due to the lack of learning resources and the teacher's role in giving support to the students.

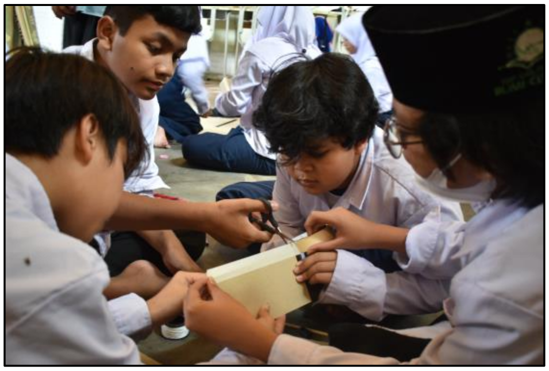

Figure 3. Students making products

In algorithm process, students have successfully tested the food box repeatedly using the success criteria, measurements, and constraints that have been formulated. However, some students only tested once, so there was no iteration of the experiment. This made it difficult for students to identify ways to improve the design and explain them. In addition to these obstacles, researchers also found other obstacles in the form of time management. teachers several times experienced a lack of time to teach a certain stage. This will certainly interfere with the next subject.

Based on the pretest-posttest results in Table 4 and the Wilcoxon test results in Table 6, it can be inferred that there is a significant difference between the pretest-posttest results of students' problem-solving skills. Meanwhile, based on the results of the N-Gain score, the average student problem solving ability increased by 0.54 after being given the treatment in the form of implementing STEM learning integrated with computational thinking. The increase is included in the moderate category. These findings are in line with the results of research handled by Arifin (2020) which stated that the STEM problem-based learning model is effective in improving students' problem-solving skills. The research finding of Lestari (2019) also stated that the application of the STEM learning can enhance students' physics problem solving skills on the concept of hydropolis pressure. Similar to these findings, Waterman et al. (2020)stated that the strategy of integrating computational thinking into STEM can develop problem solving skills in science learning, where these skills include abstraction, data, modeling and simulation, and algorithms. On the other hand, learning that is integrated with computational thinking is also proven to encourage students to think at a higher level (Dewi et al., 2018) and involves problem solving (Román-González et al., 2017). Furthermore, Barr et al. (2011) also said that computational thinking is a process of formulating problems, organizing, and implementing solutions effectively, so it will be very possible for students to be able to solve the problems faced.

STEM learning integrated with computational thinking can enhance students' problem-solving ability because this approach combines skills from various disciplines, namely science, technology, engineering, and mathematics, with logical and systematic thinking that is essential in computing. Computational thinking also allows students to break down complex problems into smaller components, more manageable parts and design solutions that can be applied incrementally (Nuzzaci, 2024). This process encourages students to think structurally and creatively in finding the best way to solve problems, which is an important skill in all aspects of STEM learning. In addition, the integration of computational thinking in STEM learning can also enhance students' learning experience by providing a more concrete and applicable context (Cheng et al., 2022). Students not only learn theoretical concepts, but also how to apply them in real situations through simulations, experiments, and problem-based projects. Thus, students learn to look at problems from multiple perspectives and consider various possible solutions, which enhances their ability to deal with complex challenges (Shongwe, 2024). This kind of learning assists students develop critical thinking skills, which are indispensable in problem solving.

The STEM approach combined with computational thinking also emphasizes the application of technology as a tool to explore and solve problems. Students are invited to use various technologies to design, test and modify their solutions. This use of technology not only accelerates the problem-solving process but also assists students develop a deeper understanding of how various STEM concepts interact and are applied in the real world (Koomanova et al., 2022). Technology mediates between theory and practice, allowing students to explore ideas in greater depth.

Furthermore, computational thinking-based learning encourages more effective collaboration and communication among students (Yin et al., 2024). When working in teams to solve problems, students learn to share ideas, discuss solutions, and combine their ideas to achieve a common goal. This collaboration not only improves students' social skills but also enriches the problem-solving process with a variety of different perspectives and approaches. By working together, students can identify mistakes and correct them collectively, which ultimately results in a more mature and effective solution.

The integration of computational thinking in STEM learning overall provides a strong framework for developing students' problem-solving abilities. By combining analytical, technological and collaboration skills, this approach prepares students to face real-world challenges with more confidence and a better ability to identify, analyze and solve complex problems. This makes STEM learning more relevant and meaningful to students, preparing them for success in a variety of careers that require high problem-solving abilities.

IV. Conclusion

Integrating computational thinking in STEM learning can be implemented well with the level of implementation reaching 88%. Although it has been implemented well, there are still obstacles that need to be overcome. The implementation of STEM learning integrated with computational thinking also affected the pretest and posttest results of students' problem-solving skills significantly. STEM learning integrated with computational thinking is also proven to enhance students' problem-solving skills. Out of 21 students, 6 students experienced a high category improvement, 10 students experienced a medium category improvement, and the other students experienced a low category improvement. Meanwhile, the average increase in students' problem-solving ability was 0.54 and included in the moderate category.

This research provides an important framework for teachers to improve the quality of mathematics learning through an interdisciplinary approach that combines computing and mathematics. The researchers suggested that future researchers can explore the effects of STEM learning integrated with computational thinking on other mathematical abilities. In addition, good time management and maximum teacher guidance are also needed in integrating computational thinking in STEM learning.

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Authors' Biography

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