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The Effect of Integrated STEM Discovery Learning Model on Computational Thinking Skills in Heat and Its Conversion Material for Grade VII Students at SMP Negeri 1 Kalasan

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Abstract

This study examined the effect of a Discovery Learning model integrated with STEM (Science, Technology, Engineering, and Mathematics) on seventh-grade students' computational thinking (CT) in the topic of heat and heat transfer. A quasi-experimental nonequivalent control group design was employed at SMP Negeri 1 Kalasan, involving two intact classes: VII B (experimental) and VII C (control). The instructional treatment embedded the Discovery Learning phases—stimulation, problem identification, data collection, data processing, verification, and generalization—within STEM activities that required students to model heat phenomena, analyze temperature–time data from simple experiments, and design testable solutions related to heat transfer and energy conversion. CT outcomes were assessed using a test aligned to core dimensions (decomposition, pattern recognition, abstraction, and algorithmic thinking), complemented by observation sheets to monitor implementation fidelity and student engagement. Data analyses indicated that the experimental class achieved significantly higher CT performance than the control class, with notable gains in decomposing heat-transfer problems, identifying patterns in empirical data, and articulating stepwise solution procedures. Observation results further revealed more active inquiry, collaboration, and iterative design behavior in the experimental group. These findings demonstrate that integrating STEM tasks into Discovery Learning effectively strengthens CT within science learning on heat and its conversion. The approach bridges conceptual understanding and procedural reasoning by engaging learners in authentic problems and guided design cycles. Practically, teachers are encouraged to incorporate structured STEM design challenges and targeted scaffolds for data interpretation and algorithmic expression. Future research should widen the sample, examine long-term retention, and explore professional development supports that sustain high-fidelity implementation.

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INTRODUCTION

Computational thinking (CT) skills are one of the fundamental 21st-century skills for students in the era of the Fourth Industrial Revolution. CT skills are a thinking process for formulating problems and devising solutions in a form that can be executed by humans or computers, through four main components: decomposition, pattern recognition, abstraction, and algorithms (Wing, 2006). This skill is essential, not only in computer science subjects, but also in interdisciplinary learning, such as Natural Sciences (IPA), which requires logical and systematic thinking.

CT skills in the context of IPA (Science) learning are becoming increasingly relevant because many scientific concepts require data analysis, modeling, and solution development based on scientific processes. The International Society for Technology in Education (ISTE) and the Computer Science Teachers Association (CSTA) (2011) define CT skills as algorithmic thinking to formulate problems, represent data abstractly, and develop solutions using tools and simulations. In fact, the Program for International Student Assessment (OECD, 2018) has included aspects of CT skills as part of scientific literacy tested in global assessments, indicating that CT skills are an important indicator in assessing students' readiness to face the challenges of the 21st century.

The fact is that CT skills among Indonesian junior high school students are still relatively low, a critical finding in various recent studies. Sa'diyyah et al. (2021) found that junior high school students in Sulawesi had difficulty in describing problems and finding patterns for solving them, which are key components of CT. Another study by Jamalludin et al. (2022) stated that the CT skills of junior high school students were low because only 2 out of 15 students were able to recognize the patterns. This is reinforced by the results of the 2021 Bebras Indonesia Challenge, which tested CT abilities at the junior high school/MTs level, where less than 1% of students obtained a score of 80 or above, and 53% of the total 1,324 students obtained score of below 60 (Bebras Indonesia, 2021). The findings from these various studies not only confirm the low level of CT skills among junior high school students nationwide but also highlight the urgency of implementing innovative learning strategies specifically designed to develop CT skills at the junior high school level.

These conditions and problems were also reflected in science learning observed during the teaching practice at SMP Negeri 1 Kalasan. Based on initial observations, students tended to memorize formulas and procedures without fully understanding the concepts. High enthusiasm in problem-based learning shows students' interest in completing challenges in practical work and the direct use of tools. However, students experience difficulties when asked to break down problems into smaller components, recognize relationships between variables, and develop solutions in the form of systematic steps. It shows that students' CT abilities are still not optimally developed.

Science learning in schools is still dominated by the lecture method, so that active students' participation is not facilitated. The low level of CT skills in science learning requires learning innovations that not only convey content but also develop CT skills. The use of the lecture method is still often found in learning activities, which can indirectly limit student activity. Low student involvement in the learning process has the potential to reduce interest, conceptual understanding, and learning outcomes (Kanza, Lesmono, & Widodo, 2020; Furmanti & Hasan, 2019).

Students' engagement or activity in the learning process is still low. One approach to overcome this problem is the Discovery Learning model. This model is designed to encourage students to discover concepts through exploratory activities, observation, and simple experiments (Roheni et al., 2020). In addition, it follows the characteristics of science learning, which requires activity and problem-solving based on real experiences. The integration of this model with the STEM (Science, Technology, Engineering, and Mathematics) approach lead to a more optimal learning because it emphasizes cross-disciplinary and applicable skills following the demands of the times (Lestari, 2022).

Previous studies, such as Setiawati et al. (2024) and Angeli et al. (2016), show that integrating Discovery Learning with the STEM approach is effective in improving higher-order thinking skills. This study focuses specifically on the development of comprehensive CT skills, especially in the context of heat and its transfer, which has not been specifically studied at the junior high school level.

Heat and its transfer are abstract topics but have many applications in everyday life (Baser, 2006; Laili et al., 2021). Understanding the concepts of heat, heat energy, calculating the amount of heat, and heat transfer by conduction, convection, and radiation requires the ability to identify patterns, make generalizations, and design solutions—all of which are core components of CT. A practical approach integrated with STEM allows students to understand the concept of heat through concrete and contextual experiences (Mardianto, 2018).

Moreover, the approach supports the characteristics of science that demand critical, analytical, and problem-solving thinking. The integration of Discovery Learning with the STEM approach encourages students to solve real problems through the integration of various disciplines. The process of independent inquiry allows students to form a more meaningful understanding while developing CT skills. Therefore, STEM learning integrated with Discovery Learning can enhance understanding of science concepts while fostering CT skills.

RESEARCH METHOD

The study used a quantitative approach with a quasi-experiment method and a Nonequivalent Control Group Design. The population consisted of seventh-grade students at a public junior high school, located in Yogyakarta during the second semester of the 2024/2025 academic year. The research design is described in Table 1.

Table 1. Nonequivalent Pretest-posttest Control Group Design

Group	Pretest	Treatment	Posttest
Experiment Class	O_1	X_1	O_3
Control Class	O_2	-	O_4

The sample was selected using cluster random sampling. Class VII B plays as the experiment class that received the STEM-based Discovery Learning model. Meanwhile, class VII C plays as the control class that received the scientific Discovery Learning model. This technique was selected because it facilitates sampling while maintaining the integrity of the group and the natural classroom atmosphere, and reduces the risk of bias that might arise if sampling were done randomly on individuals. Randomization was conducted at the class (cluster) level. So, each class had an equal chance of becoming an experiment or control class.

Data collection instruments consisted of tests and non-tests. Test instruments included pretest and posttest essay questions to measure computational thinking (CT) abilities, while non-test instruments included observation sheets on the implementation of learning and validation sheets. The test questions were developed based on four CT indicators, namely decomposition, pattern recognition, abstraction, and algorithms (Anggrasari, 2021).

Data collection was conducted in two stages: a pretest before the treatment and a posttest after the treatment in both classes. The validity of the questions was analyzed using Pearson's correlation, and reliability was tested using Cronbach's Alpha.

Data analysis techniques included descriptive statistics, normality tests (Shapiro-Wilk), homogeneity tests (Levene's Test), independent sample t-tests to test differences between groups, and effect size calculations to determine the level of the treatment effect.

RESULT AND DISCUSSION

The study aims to determine the differences and impacts of the STEM-based Discovery Learning model on students' computational thinking skills. Data were collected through pre-tests and post-tests. In addition, it analyzed using descriptive and inferential statistics.

The results of the study was obtained through data analysis of the computational thinking (CT) abilities of seventh-grade students at SMP Negeri 1 Kalasan on the subject of heat and its transfer. Data analysis were descriptive statistics, difference tests using independent sample t-tests, and effect size calculations.

The results of the descriptive statistical analysis were presented to illustrate the students' CT abilities based on the pre-test and post-test written test data. The pre-test was administered before the learning treatment. Meanwhile, the post-test was conducted after the treatment. The purpose of the two tests was to determine the students' initial abilities and changes in their abilities after participating in the learning process. Descriptive analysis was conducted to obtain an overview of the pre-test and post-test results. Details of the descriptive statistical analysis results for the control class and experiment class is presented in Table 2.

. **Table 2.** Descriptive Statistical Analysis Data Results

Value	Control Class		Experiment Class	
N Valid	32	32	32	32
Standard Deviation	15,18	14,41	13,72	10,55
Variance	230,544	207,661	188,306	111,290
Minimum Value	20	25	20	45
Maximum Value	80	85	80	95
Average	57,19	66,87	49,37	73,75

The results of the comparison between the experiment class and the control class show that the experiment class experienced a more significant improvement, both in terms of average scores and distribution of learning outcomes, than the control class. These findings indicate that the application of the Discovery Learning model integrated with the STEM approach is not only effective in improving students' CT abilities but also contributes to creating a more even and consistent distribution of students' learning outcomes. The graph in figure 1 shows the frequency of the average pretest and posttest scores for CT abilities in the experiment and control classes to support these findings.

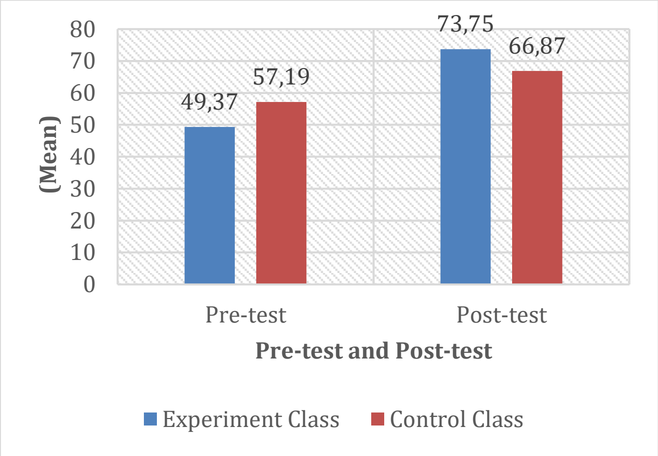

Figure 1. Frequency Graph of Mean on Pre-test and Posttest Scores for CT Ability

Based on Figure 1, a comparison of the average pretest and posttest scores between the experimental and control classes obtained through the written test results of five description questions is presented. The questions were systematically designed to measure students' CT ability by covering four main aspects, namely two items that measure decomposition ability, one item that measures pattern recognition, one item that assesses the abstraction aspect, and one item that tests the ability in algorithmic thinking.

The data visualization in the graph in Figure 1 shows a quite striking difference between the two classes, where the experiment class shows a more significant increase than the control class. It shows that the application of the Discovery Learning model integrated with the STEM approach provides a more optimal and effective influence in improving students' overall CT skills compared to the Discovery Learning scientific approach, applied in the control class.

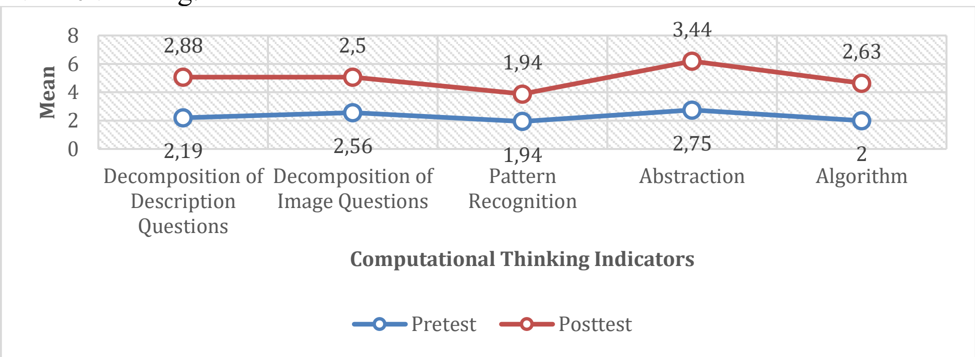

Figure 2. Frequency Graph of Average Scores for CT Ability Test Items in the Control Class

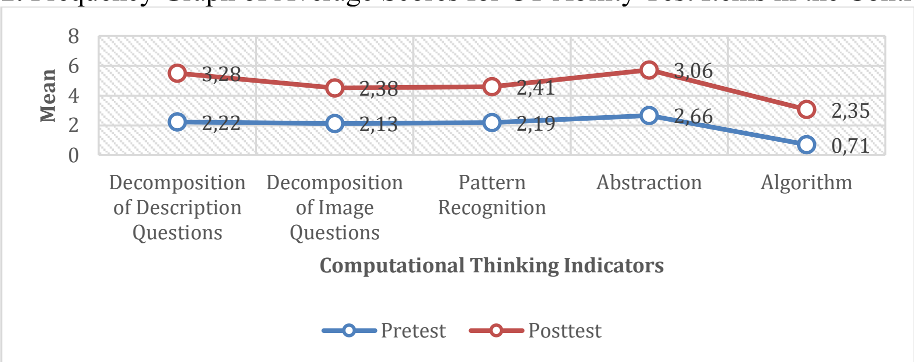

Figure 3. Frequency Graph of Average Scores for CT Ability Test Items in the Experiment Class

In general, the graph of the control class's CT ability indicators shows an increase in scores for most indicators, although the level of change varied. Meanwhile, the graph of the experiment class's CT ability indicators shows that all aspects of CT ability improved after students received

Discovery Learning treatment with a STEM approach in the experiment class.

The pretest and posttest scores were analyzed using a homogeneity test. The homogeneity test was conducted to ensure that the data manipulated in a series of analyses originated from a population with homogeneous variance (Widana & Muliani, 2020). The criteria for decision-making in the homogeneity test with a 95% confidence interval or 5% significance level, according to Widana & Muliana (2020), are as follows.

a. If the sig. Based on the Mean value being > 0.05, the data is declared homogeneous.
b. If the sig. Based on the Mean value being < 0.05, the data is declared non-homogeneous.

Table 3. Homogeneity Test Results

Types of Tests	Sig. (Based on Mean)	Criteria
Pre-test	0,319	Homogeneous
Post-test	0,078	Homogeneous

Based on Table 3, the homogeneity test show that the significance value (Sig.) for the pretest data is 0.319 and for the posttest data is 0.078. Both values are higher than 0.05. So, it concluded that the pre-test and post-test data between the control class and the experiment class have homogeneous variance.

The data have been declared homogeneous, so data analysis with hypothesis testing is proceed. The hypothesis test was conducted using an independent sample t-test to determine whether there was a difference in the means of two unpaired samples. The independent sample t-test was conducted to see a difference in the pretest and posttest results of students in the experiment class using the Discovery Learning model with a STEM approach and the control class using the Discovery Learning model with a scientific approach.

The data have been declared homogeneous, so data analysis with hypothesis testing is proceed. The hypothesis test was conducted using an independent sample t-test to determine a difference in the means of two unpaired samples. The independent sample t-test was conducted to see a difference in the pretest and posttest results of students in the experiment class using the Discovery Learning model with a STEM approach and the control class using the Discovery Learning model with a scientific approach. The results of the independent sample t-test for CT ability pretest scores of the control class and experiment class is presented in Table 4.

Table 4. Independent Sample t-Test Results for CT Ability Pre-test Scores

CT Ability	Levene's Test	Independent Sample t-Test		
	Sig.	t	df	Sig. (2-tailed)
Assumption that the two variances are equal	0,319	2,159	62	0,035

The results of the independent sample t-test for pretest scores show that the significance value (Sig. 2-tailed) is 0.035, which is higher than the significance level of 0.025. Therefore, the two classes are considered to have relatively equal initial abilities before the treatment. The significance value of the pretest is higher than the specified significance level. It means that H_0 is accepted and H_1 is rejected. Therefore, there is no significant effect of the treatment at the initial stage of learning.

Table 5. Independent Sample t-Test Results for CT Ability Posttest Scores

CT Ability	Levene's Test	Independent Sample t-Test		
	Sig.	t	df	Sig. (2-tailed)
Assumption that the two variances are equal	0,129	2,559	62	0,013

Based on Table 5, the significance value (Sig. 2-tailed) of 0.013 < 0.025 indicates a significant difference between the posttest scores of the experiment and control classes. It concluded that H_0 is rejected and H_1 is accepted. Therefore, the Discovery Learning model with a STEM approach has a significant effect on improving students' CT abilities.

The effect size test was used to determine the effect of Discovery Learning model with a STEM approach on students' CT abilities. The effect size in this study was calculated using Cohen's d formula (Cohen, Manion, & Morrison, 2018):

$$ES = \frac{M_e - M_c}{SD}$$

The criteria for determining the effect size follow the effect size criteria according to Cohen, Manion, & Morrison (2018):

Table 6. Homogeneity Test Results

d Value	Category
0,00 - 0,20	Weak effect
0,21 - 0,50	Moderately weak effect
0,51 – 1,00	Moderate effect
d > 0,8	Strong effect

Source: Cohen, Manion, Morrison (2007)

The analysis was conducted using effect size calculations to determine the effect produced by the Discovery Learning model treatment with a STEM approach to the experiment class. The effect size test results are presented in Table 7.

Table 7. Effect Size Test Results

Class	Mean	Standard Deviation
Control	66,88	14,410
Experiment	73,75	10,549
Effect Size (d)	**0,544**	**Moderate**

Based on the effect size calculation results for CT ability, a value of 0.544 was obtained, which is classified as moderate. This value indicates that the Discovery Learning model with a STEM approach applied in the experimental class had a significant effect compared to the Discovery Learning model with a scientific approach in the control class. These results show that the integration of the STEM approach in the Discovery Learning model is effective in improving students' CT abilities.

The study proved that the application of the integrated STEM Discovery Learning model has a positive effect on improving the Computational Thinking (CT) skills of seventh-grade students at SMP Negeri 1 Kalasan in the subject of heat and its transfer. The difference between the experimental class and the control class shows that the use of the STEM approach provides a more in-depth learning experience compared to science-based learning, which is generally still limited to mastery of concepts and memorization.

Combining the Discovery Learning model with STEM creates a learning environment where learners actively explore science concepts through technology and engineering-based projects. The Discovery Learning model integrated with STEM is much more capable of increasing the level of understanding of concepts in students. The STEM approach improves students' understanding of concepts because the it includes four disciplines, namely Science, Technology, Engineering and Mathematics which focus more on the learning process for problem solving related to everyday life. Therefore, students are directly involved in learning activities and more active (Gustiani et al., 2017; Suhery, 2017; Wulandari et al., 2019).

The syntax in Discovery Learning includes stimulation, problem identification, data collection, data processing, proof, and conclusion drawing, all of which are aligned with STEM characteristics, presented in Table 8.

Table 8. Stages of Experimental Class Learning Process with STEM Integrated Discovery Learning Model

Syntax	Learning Activities	STEM Aspects
Stimulus	The teacher opens the lesson by showing a video about the importance of energy efficiency in everyday life, such as energy-efficient houses and heat storage technology (thermos). The teacher asks triggering questions: "Why do houses in cold areas need heat insulation?" and "How can a thermos maintain the temperature of water?" Next, the teacher divides the learners into 4 groups and conveys the objectives and steps of the project.	***Science*** – students are introduced to the initial concept of heat and its transfer through real-life phenomena.
Problem Identification	Students observe videos of various phenomena in everyday life related to heat, such as drying clothes outside the house, which will dry faster than drying clothes inside the house due to conduction heat transfer. Furthermore, at the next meeting, students observe a video about fish cooked in a burnt pan; the fish also burns because the pan is a conductor object. Students are asked to listen to the video well, and the teacher distributes LKPD (student worksheet) to students, where the LKPD have questions about the problems that will be solved in the project.	***Science & Technology*** – students begin to understand the physical problem and the technological possibilities for its solution.

Data Collection	Students begin to search for answers to the questions contained in the LKPD and conduct discussions in their own groups. Each group designs a project-based solution. Students look for references to materials and working principles from various sources and begin to develop initial product designs. The teacher facilitates discussion and initial testing of materials.	***Technology & Engineering*** – students are directly involved in the design and assembly of products with an engineering approach.
Data Processing	The teacher distributes the practical LKPD to students, and guides learners to carry out practical activities. Students test their design after the heat treatment. Temperature data is observed in certain time intervals and then calculated using the formula to find the amount of heat and insulation effectiveness.	***Mathematics*** – Students process observation data (temperature and time) and draw connections between experimental results and the principle of heat.
Evidence	Groups present their project results in front of the class by explaining the manufacturing process, the connection with heat and its transfer, and the test results. Other groups provide responses and questions. The teacher facilitates scientific discussions to deepen concept understanding.	***Science & Engineering*** – substantiation through scientific discussion and testing of work.
Conclusion	Students and teacher conclude the basic principles of heat transfer, the effectiveness of insulating materials, and the relationship between the concept of heat and its application in life. Conclusions are drawn from direct experience, data analysis, and group discussion.	Integrated (*Science, Technology, Engineering, Mathematics*)

Table 9 presents two learning projects integrated with the STEM approach designed to develop students' understanding of the concept of heat and its transfer in the experimental class. Each project integrates the four aspects of STEM, namely Science, Technology, Engineering and Mathematics, in an integrated manner in the learning activities.

Table 9. STEM Aspects in Science Learning about Heat and Its Transfer

STEM Project	**STEM Aspects**			
	Science	***Technology***	***Engineering***	***Mathematics***
Energy Efficient Home	Learning how heat moves through conduction, convection, and radiation	Using thermometers /temperature sensors to record and analyze temperatures	Design house models with materials and structures that can reduce heat loss.	Calculating temperature change
Thermos	Understand the concept of heat and heat transfer	Use a thermometer to periodically measure the water temperature	Design and manufacture of thermos structure	Calculating temperature change
	Observe and compare changes in water temperature	Using a stopwatch to to record time	Adding an insulating layer (tissue, aluminum	Calculate the heat lost using the formula $Q = m . c . \Delta T$

Classify materials as conductors or insulators of heat	foil) to reduce heat loss.

Discovery Learning-based learning integrated with STEM leads students not only to receive knowledge, but also to discover, explore, and connect science concepts with real contexts. The learning process through the stages of stimulation, problem formulation, data collection, data processing, proof, and conclusion helps students train the four CT indicators, namely decomposition, pattern recognition, abstraction, and algorithmic thinking.

Decomposition

The decomposition ability of students in the experimental class increased and obtained higher score than of the control class, seen from their skills in breaking down complex problems, such as differences in heat transfer rates in various insulating materials, into simpler sub-problems. In the STEM-integrated Discovery Learning process, students are asked to design an experiment and divide the steps of the investigation into coherent stages. This activity helps students practice analytical skills, so they can understand the problem thoroughly. with the finding support the findings of Sa'diyyah et al. (2021), who stated that decomposition can be trained through project-based scientific inquiry activities.

Pattern Recognition

The pattern recognition indicator also showed a significant increase in the experimental class. Students find patterns of relationships between the variables of temperature, time, and type of insulating material in the experiments. By observing the results of repeated measurements, they can conclude that materials with high specific heat are slower to change temperature. The STEM approach supports this aspect because it requires students to link the experimental data with the physics concepts. In line with the research of Jamalludin et al. (2022), pattern recognition skills improve when students engage in empirical data-based activities.

Abstraction

Abstraction is the ability to filter an important information and ignore irrelevant things. In the experimental class, students can identify the basic principles of heat transfer and link it to everyday life, for example, the function of a thermos or energy-efficient home design. In STEM-integrated Discovery Learning, abstraction is facilitated through group discussions, where students are asked to summarize the main findings of the experiment. This activity helps them generalize scientific principles from concrete data. The results of this study support Mgova's (2018) study that STEM integration can develop abstraction skills by emphasizing the application of concepts across disciplines.

Algorithmic Thinking

Students' algorithmic thinking skills are improved through the practice of composing problem-solving steps logically and systematically. In the experimental class, students were asked to calculate the amount of heat transferred based on experimental data using the formula $Q = m \times c \times \Delta T$. This process requires them to develop appropriate calculation procedures, starting from data collection, substitution of values, and interpretation of results. This activity familiarizes students with coherent and structured thinking. In line with Wing's (2006) opinion, algorithmic thinking is at the core of CT as it helps design solutions that can be implemented.

The results of this study are consistent with the findings of Setiawati et al. (2024), which showed that the integration of Discovery Learning and STEM can improve higher-order thinking skills. In addition, Angeli et al. (2016) stated that STEM-based learning is effective in developing problem-solving skills and CT more broadly. With an effect size of 0.544 (moderate category), this study confirms that the effect of STEM integration on CT is quite real and effective alternative for science learning.

Moreover, STEM-integrated Discovery Learning has an impact on affective aspects. Students showed higher engagement, enthusiasm in group work, and more confidence in presenting the results. Project-based learning allows them to play an active role. In contrast, students of the control class tend to be passive due to the dominance of the lecture method. This condition supports Furmanti & Hasan's (2019) opinion that active learning increases students' motivation and participation.

Also, this finding supports the research of Lestari (2022) and Ningkaula et al. (2021), which showed that STEM integration in science learning is effective in improving higher-order thinking skills. Discovery Learning syntax, consisting of stimulation, problem identification, data collection, data processing, verification, and generalization, proved to be in line with STEM (Science, Technology, Engineering, Mathematics) aspects. For example, at the data processing stage, students not only conduct experiments, but also calculate the effectiveness of heat insulation using mathematical principles.

Learning with STEM integration can bridge abstract concepts in heat material into concrete experiences. Materials, such as conduction, convection, and radiation, are usually difficult to understand, but the concepts become ease through real experiments and simple projects that are relevant to everyday life. Thus, students more easily understand scientific concepts while training logical and systematic thinking skills, that follow the characteristics of science as a subject and emphasizes the integration of knowledge, attitudes, and scientific process skills.

The results of this study confirm that the STEM-integrated Discovery Learning model has a positive effect on students' CT ability, with a moderate level of influence. This integration not only improves the understanding of science concepts but also prepares learners to face the challenges of the 21st century that demand critical, creative, and computational thinking skills.

CONCLUSION

Based on the finding dan discussion, it can be concluded that the application of the integrated STEM Discovery Learning model has a positive effect on students' Computational Thinking (CT) abilities in the subject of heat and its transfer in grade VII at SMP Negeri 1 Kalasan. Students who received STEM-integrated learning showed an improvement in CT abilities compared to their pre-existing abilities, particularly in aspects, such as decomposition, pattern recognition, abstraction, and algorithmic thinking. This is evidenced by an increase in scores after learning. Moreover, the analysis results show an effect size of 0.544, which is in the moderate category.

This learning model encourages students to be more active in exploring concepts, conducting experiments, and linking scientific knowledge with the application of technology, engineering, and mathematical calculations. This process not only strengthens their understanding of the concepts of heat and its transfer, but also fosters systematic, critical, and creative thinking skills, which are at the core of CT abilities. Therefore, integrated STEM Discovery Learning can be used as an effective alternative learning strategy to improve the quality of science education while preparing students to meet the demands of 21st-century skills.

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