The effect of metacognitive scaffolding-based student worksheets on junior high school students' argumentation skills in science learning

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Article History
Received: 4 January 2026
Revised: 25 February 2026
Accepted: 30 March 2026
Published: 6 April 2026

Keywords
Argumentation skills
Metacognitive scaffolding
Student worksheets

Abstract
Argumentation skills are a vital competence in 21st-century learning, playing a crucial role in developing students' critical thinking and communication abilities. However, preliminary observations indicate that students' argumentation skills at the junior high school level, specifically at senior high school 2 Panti, remain low. Although active student engagement during the learning process is critical, empirical studies on the use of metacognitive scaffolding-based worksheets to address this issue in science learning are still limited. This study aims to investigate the effect of metacognitive scaffolding–based student worksheets on students' argumentation skills to contribute to effective science teaching practices. This study employed a quasi-experimental method with a one-group pretest-posttest design. The research subjects consisted of 28 seventh-grade students (Class VII E) at senior high school 2 Panti during the odd semester of the 2025/2026 academic year. The research instrument utilized an argumentation skills essay test administered during the pretest and posttest phases, assessing three specific indicators: claim, evidence, and reasoning. Data were analyzed using descriptive statistics and a paired sample t-test. The results showed a significant increase in the mean argumentation score from 30.68 (pretest) to 76.64 (posttest). which was statistically supported by a paired sample t-test ($p < 0.001$). Based on these findings, it is concluded that student worksheets based on metacognitive scaffolding have a significant effect on students' argumentation skills. Consequently, this approach offers a specific contribution to the design of metacognition-based science teaching materials.

How to cite: Masruri, A. F., Rusdianto, R., Iffah, F., Amrullah, J. D. R., & Shilla, R. A. (2026). The effect of metacognitive scaffolding-based student worksheets on junior high school students' argumentation skills in science learning. *Journal of Environment and Sustainability Education, 4*(2). 259–266. doi: 10.62672/joease.v4i2.218

1. Introduction

Argumentation is a pivotal skill that students must possess in science learning, as it constructs logical reasoning and rational explanations regarding the studied material (Osborne, 2010). Through argumentation, students demonstrate the ability to formulate claims, provide evidence, and construct scientific reasoning to defend their arguments (Zhu et al., 2020). This skill assists in enhancing theoretical understanding, facilitates problem-solving, and supports appropriate decision-making (Fatma et al., 2024).

One essential skill in 21st-century learning is argumentation, as it contributes directly to developing students' critical thinking and communication abilities (Devy et al., 2020). Argumentation skills are implemented through the Claim, Evidence, and Reasoning (CER) framework developed by McNeill and Martin. This structure serves to elucidate the logical relationship between statements, evidence, and reasoning, thereby facilitating the construction of coherent arguments based on empirical data. A claim is defined as an idea, notion, or statement to address a specific problem. Evidence refers to the scientific proof or data used to support the claim. Reasoning is the scientific explanation used to clarify why the evidence supports the established claim (McNeill & Martin, 2011). Argumentation skills train students to think logically, maintain a focused perspective, and provide rational explanations for the material they have studied (Arfiany et al., 2021). According to Hasanah et al (2022), argumentation skills enable students to articulate acquired knowledge supported by strong evidence and ideas, thereby producing logical conclusions. Consequently, argumentation skills facilitate students' understanding of scientific concepts regarding scientific phenomena occurring in daily life (Halimah et al., 2020).

doi: 10.62672/joease.v4i2.218

ISSN: 3025-0714

Based on preliminary observations conducted, the argumentation skills of students at junior high school 2 Panti remain relatively low, particularly in science learning on physics topics. This finding aligns with the research by Riwayani et al (2019), which indicates that the argumentation skills of junior high school students are still categorized as low, with an obtained argumentation skill score of 63.71 points, which is significantly below the maximum score of 100 points. Research by Rahayu et al (2020) further indicates that students' argumentation skills are positioned at level 1 or 2, categorized as low. At these levels, students tend to present general opinions but remain unable to accurately correlate claims with scientific data and evidence (Hasanah et al., 2022). This deficiency in argumentation skills is attributed to the lack of students' active engagement in discussions during the learning process. In practice, teachers tend to evaluate learning by checking answers and providing brief explanations (Trisnawati et al., 2025). Although Azizah et al (2025) emphasize the significance of student metacognition in supporting argumentation skills through the connection between claims, evidence, and reasoning, its practical implementation remains a challenge. Hidayati et al (2025) state that this difficulty stems from the lack of teacher facilitation in metacognitive activities that align with the metacognitive stages of planning, monitoring, and evaluating. Consequently, while the conceptual link between metacognition and argumentation skills has been extensively discussed in theoretical studies, a research gap persists regarding the availability of instructional materials that systematically integrate metacognitive scaffolding within Student Worksheets. Such integration is essential to bridge the role of teacher guidance toward students' metacognitive self-regulation in developing argumentation skills within junior high school science learning.

The metacognitive scaffolding approach holds potential for addressing these issues by providing gradual assistance that encourages students to recognize and control their own thinking processes. In the context of science learning, the application of metacognitive scaffolding can assist students in understanding data, compiling relevant evidence, and constructing scientific reasoning that supports claims (Fadillah et al., 2018). One potential and contextual form of implementation in the classroom is through Student Worksheets designed systematically to guide students' thinking activities during the learning process (Rusdianto et al., 2024). Student Worksheets containing metacognitive prompting questions and scaffolding assistance have the potential to improve the quality of students' argumentation by guiding them to reflect on their understanding, evaluate evidence, and logically connect concepts. Thus, metacognitive scaffolding-based Student Worksheets can serve as a practical and effective solution to improve junior high school students' argumentation skills in science learning.

Various studies have been conducted to improve students' argumentation skills using innovative teaching materials. Recent research by Kinanthi and Azizah (2025) indicates that the use of Argument-Driven Inquiry (ADI)-based Student Worksheets can improve argumentation skills to a high category. Similarly, research by Hasnunidah et al (2025) shows that the development of ADI-STEM-based e-liveworksheets can increase argumentation skills with an N-Gain value in the high category. However, both studies rely on the ADI learning model, which focuses on inquiry stages. To date, no research has explicitly integrated the metacognitive scaffolding approach into teaching materials in the form of Student Worksheets to improve students' argumentation skills. Therefore, this study focuses on examining the effect of using metacognitive scaffolding-based Student Worksheets in improving students' argumentation skills in science learning to fill the existing research gap. In line with this objective, this study hypothesizes that the use of metacognitive scaffolding-based student worksheets has a positive effect on students' scientific argumentation skills. This approach is designed to guide students in planning, monitoring, and evaluating their thinking processes, thereby facilitating the construction of arguments grounded in valid data and scientific concepts.

2. Method

2.1. Research Design

This study employed a One-Group Pretest–Posttest quasi-experimental design on one sample class utilizing instruction using metacognitive scaffolding-based student worksheets. A pretest was administered to assess students' initial argumentation skills, followed by a posttest after the tervention (Maciejewski, 2018; Stratton, 2019). The selection of this design was based on practical constraints and school policies that precluded random assignment; therefore, the research utilized one available intact class. Despite the limitation of lacking a comparison group, this design examines the empirical comparison of students' argumentation skills before and after the intervention. Furthermore, potential threats to internal validity, specifically testing and maturation effects, were controlled by ensuring the consistency of instructional delivery and classroom conditions during the research. The scheme of this research design is presented in Table 1.

Table 1. Research Design

Group	Pretest	Treatment	Posttest
(R)	O1	X	O2

Table 1 indicates that (R) represents the experimental class, O_1 denotes the pretest administration, X represents the learning intervention using metacognitive scaffolding-based Student Worksheets, and O_2 denotes the posttest administration.

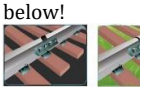
2.2. Participants

The participants in this study were active seventh-grade students enrolled in the odd semester of the 2025/2026 academic year at senior high school 2 Panti, Jember Regency, East Java, Indonesia. The sample consisted of Class VII E, selected using the convenience sampling technique. The study commenced after obtaining formal permission from the school administration under reference number 400.3.5/359/35.09.310.17.20523860/2025. All students participated voluntarily, with the assurance that their involvement would not impact their academic assessment. Furthermore, all data were collected anonymously and utilized exclusively for research purposes.

2.3. Instrument

The instrument employed to measure students' argumentation skills was a nine-item essay test covering temperature, heat, and expansion, developed based on McNeill and Martin's (2010) CER framework. The test items were adapted from Fatma et al (2024) with necessary adjustments to the learning materials. Prior to the intervention, the items were validated by three experts, yielding average validity scores of 97.84 (pretest) and 98.77 (posttest), classifying the test as very valid and suitable for data collection. The data analysis technique employed in this study was the paired sample t-test, which aimed to determine the improvement in students' argumentation skills before and after the implementation of the metacognitive scaffolding-based student worksheets. Additionally, Cohen's d was calculated to assess the magnitude of the effect size. All data processing and analysis were conducted using IBM SPSS Statistics 16 software. The details of the research instrument, comprising the aspects of argumentation skills, indicators for each aspect, sample questions, answers, and scoring guidelines, are presented in Table 2.

Table 2. Specification of Argumentation Skills Instrument

Argumentation Skill Aspect	Assessment Indicators	Example Question		Answer Key	Scoring Guidelines
Claim	Students are able to formulate a claim based on observed phenomena	Observe the Science phenomenon below!  Statement 1: Railway track gaps become narrower during the day because high temperatures cause the rails to expand. Statement 2: Railway track gaps become narrow because the rails contract at high temperatures.	a. Which statement do you agree with? Explain your reason!	I agree with statement 1. During the day when the temperature is high, metal rails expand so the gap becomes narrow.	a. Students state the correct statement (Statement 1) and explain that rails expand at high temperatures so the gap narrows. (Score 4) b. Students choose the correct statement and explain expansion, but without mentioning the concept in detail. (Score 3) c. Students choose the correct statement but the reason is simple, e.g., "because of heat". (Score 2) d. Students only choose a statement or the reason is irrelevant. (Score 1) e. Students do not answer or the answer is completely wrong. (Score 0)
Evidence	Students are able to include scientific data or facts to support the claim.		b. Write down evidence from the phenomenon that supports your answer!	During the day the rail gap appears narrower, whereas at night when the air is colder, the gap widens again.	a. Students mention complete evidence: during the day the gap becomes narrow, at night the gap becomes wide. (Score 4) b. Students mention that during the day the gap is narrow, without mentioning the night condition. (Score 3) c. Students state generally that the gap changes when hot, without details. (Score 2) d. Student answers are ambiguous or irrelevant. (Score 1) e. Students do not answer or the answer is completely wrong. (Score 0)
Reasoning	Students are able to connect evidence to the claim using scientific concepts		c. Provide an explanation regarding the evidence you have provided	When the temperature rises, particles in the metal move faster and the average distance between particles	a. Students explain metal expansion: particles move faster, distance increases, rail length increases so the gap becomes narrow; and vice versa at night. (Score 4) b. Students explain that rails expand because of heat, without particle details. (Score 3) c. Students provide a simple reason without scientific concepts. (Score 2)

Argumentation Skill Aspect	Assessment Indicators	Example Question	Answer Key	Scoring Guidelines
		by using appropriate Science concepts !	increases, so the rail length increases (expands). This is the reason why the gap becomes narrow during the day. At night the temperature drops, the rails contract so the gap widens again.	d. Student explanation is illogical (e.g., "because rails contract when hot"). (Score 1) e. Students do not answer or the answer is wrong. (Score 0)

3. Results and Discussion

This research was conducted at senior high school 2 Panti over eight sessions from October 2 to October 30, 2025. Each session lasted for 80 minutes. The research sample consisted of 28 students from Class VII E. In the first session, students were administered a pretest to measure their initial argumentation skills. Subsequently, from the second to the seventh session, students participated in learning activities using metacognitive scaffolding-based Student Worksheets on the topics of Temperature, Heat, and Thermal Expansion. In the eighth session, a posttest was administered to assess students' argumentation skills following the treatment. A summary of the students' pretest and posttest results is presented in Table 3.

Table 3. Average Pretest and Posttest Results

Descriptive Statistics					
	N	Minimum	Maximum	Mean	Std. Deviation
Pretest	28	8	58	30.68	12.835
Posttest	28	50	94	76.64	9.738
Valid V (listwise)	28				

Table 3 demonstrates an increase in the mean score of the argumentation skills test from 30.68 to 76.64, indicating a significant improvement following the intervention. The reduction in standard deviation (from 12.835 to 9.378) suggests that the variation in student abilities has narrowed, implying that students' understanding in constructing scientific arguments became more uniform after the intervention. Before conducting hypothesis testing, the pretest and posttest data were subjected to prerequisite analysis using the Shapiro-Wilk normality test. Data are considered normally distributed if the significance level is greater than 0.05 (Sig. > 0.05). The normality test results presented in Table 4 indicate that the significance value for the pretest data was 0.567 and for the posttest data was 0.876. Both values exceed 0.05; therefore, the data on students' argumentation skills before and after the treatment are declared to be normally distributed.

Table 4. Results of The Normality Test for Pretest-Posttest Data

Tests of Normality Shapiro-Wilk			
	Statistic	df	Sig.
Pretest	.969	28	.567
Posttest	.981	28	.876

Upon satisfying the prerequisite analysis assumptions, the next stage involved hypothesis testing using the paired sample t-test to determine if there was a significant difference in students' argumentation skills before and after the implementation of the metacognitive scaffolding-based student worksheets during the learning process. The paired sample t-test results, as detailed in Table 5, show that the obtained pretest-posttest significance value was 0.000, which is less than 0.05 (0.000 < 0.05). This indicates a significant difference between the pretest and posttest mean scores. These findings demonstrate that the null hypothesis (H0) is rejected and the alternative hypothesis (H1) is accepted, leading to the conclusion that the implementation of metacognitive scaffolding-based student worksheets has a significant effect on students' argumentation skills.

Table 5. Results of The Paired Sample T-Test

Paired Samples Test	
	Sig. (2-tailed)
Pretest-Posttest	.000

Based on the data analysis performed, it is evident that the utilization of metacognitive scaffolding-based student worksheets influences students' argumentation skills. This strong influence is quantified by a Cohen's d effect size of 4.07, falling into the very large category. This is attributed to the fact that the activities within the metacognitive scaffolding-based student worksheets incorporate learning tasks focused on argumentation skill indicators. Furthermore, the use of a metacognitive approach within the student worksheets assists students in regulating their thinking processes in a systematic and structured manner. The metacognitive approach refers to three stages: planning, monitoring, and evaluating (Azizah et al., 2025). Additionally, the provision of scaffolding in the form of guiding statements helps students organize ideas in a structured way and link each argument with relevant evidence or data (Hidayati et al., 2025). The application of metacognitive scaffolding is carried out by posing reflective questions, such as "what," "how," and "why," as an effort to deepen the understanding of a concept (Azizah et al., 2023). In summary, these findings confirm that integrating metacognitive scaffolding into student worksheets effectively enhances students' argumentation skills by promoting structured and reflective thinking.

3.1. Claim Indicator

Activities in the metacognitive scaffolding-based student worksheets are designed with reference to three indicators of argumentation skills: claim, evidence, and reasoning. The first indicator, claim, is a statement or response to a question that serves as the foundation for argument formation (McNeill & Martin, 2011). In the designed activities, the formulation of a claim is explicitly connected to a scientific phenomenon acting as a stimulus. For instance, students first examine a narrative regarding the tactile difference between hot and cold water. Based on this phenomenon, they are prompted to answer a specific question: "*Make an initial claim (opinion) regarding the temperature of hot water compared to the temperature of cold water?*". This sequence of analyzing the phenomenon followed by formulating a claim ensures that student responses are grounded in observation. Consequently, this activity stimulates students' critical thinking and fosters their ability to articulate initial statements that are logical, relevant, and scientifically testable as a basis for subsequent argument construction (Diola et al., 2025). The details of the claim indicators in the metacognitive scaffolding-based student worksheet are presented in Figure 1.

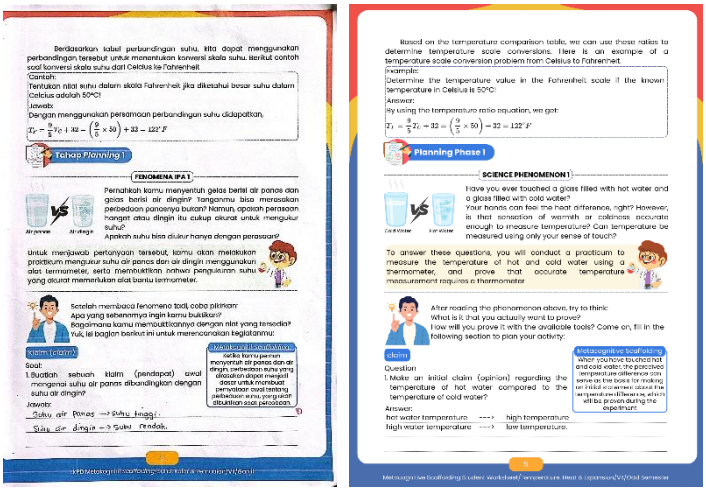


Figure 1. Claim Indicators
(on the left: original version; on the right: English translation)

3.2. Evidence Indikator

The second indicator is evidence, defined as scientific proof or data that supports the claim (McNeill & Martin, 2011). The evidence indicator requires students to provide accurate proof based on data, facts, information from images, or presented problems to support their claim (Wangmo et al., 2025; Daraman et al., 2025). Students capable of including data or evidence find it easier to convey their arguments effectively (Rahayu et al., 2020). In the developed Student Worksheets, the construction of evidence is designed as a sequential process following the claim formulation. Initially, students analyze a scientific phenomenon regarding the thermal properties of hot and cold water to state a claim. To substantiate this claim, they must conduct a practical experiment. The specific prompt for this stage is: "*Perform the temperature measurement experiment! Record the measurement results in the observation table!*". By generating data through direct observation, students obtain concrete evidence. This activity trains students to link observation results with their proposed claim while enhancing precision and metacognitive awareness in monitoring the accuracy of the data used as evidence (Dewi et al., 2025). The details of the evidence indicators in the metacognitive scaffolding-based student worksheet are presented in Figure 2.

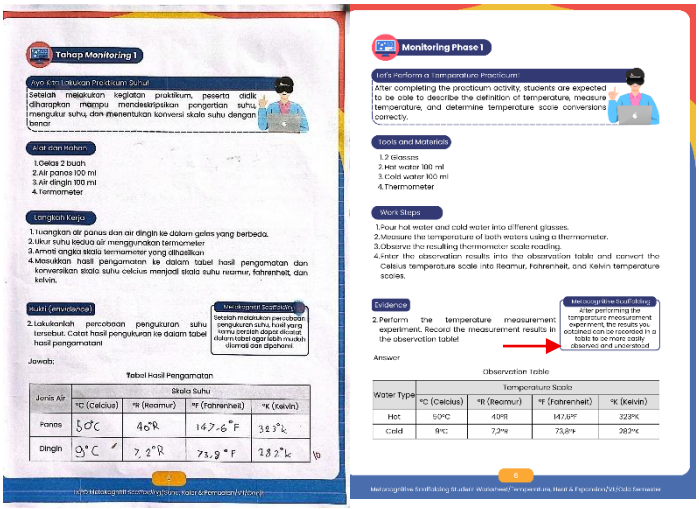


Figure 2. Evidence Indicators
(on the left: original version; on the right: English translation)

3.3. Reasoning Indicator

The third indicator is reasoning, which serves as the justification for how or why the evidence supports the claim using scientific explanations (McNeill & Martin, 2011). This indicator asks students to explain the logical relationship between the evidence and the claim through scientific explanation, thereby producing a robust argument (Ekawati et al., 2025). In the structure of the developed Student Worksheets, the reasoning task functions as the final synthesis step. After formulating a claim based on the phenomenon of thermal properties and gathering empirical data through the experiment (evidence stage), students are required to articulate the underlying scientific principles. Specifically, the prompt asks: "*Explain the scientific reason why your experiment results (evidence) regarding the measurement of hot and cold water temperatures support the claim you made!*". This step ensures that students do not merely present data but actively construct a logical bridge linking their empirical findings back to their initial claim. This activity trains students' ability to connect empirical evidence with claims through scientific principles and concepts, while simultaneously encouraging metacognitive awareness in evaluating the accuracy and logic of the arguments they construct (Wangmo et al., 2025). The details of the evidence indicators in the metacognitive scaffolding-based student worksheet are presented in Figure 3.

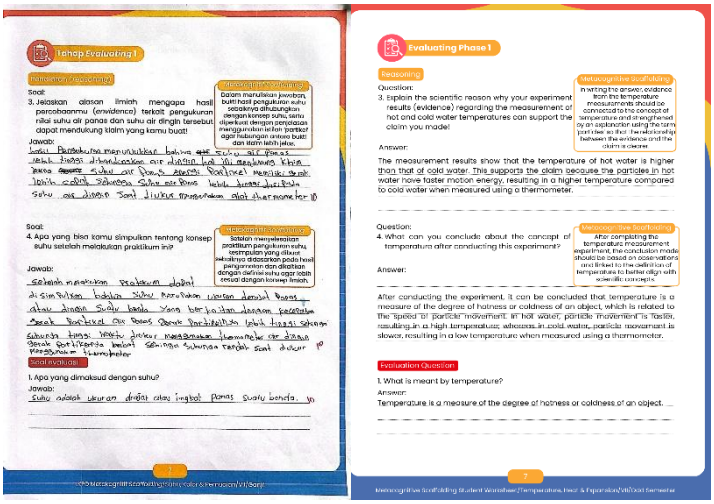


Figure 3. Reasoning Indicators
(on the left: original version; on the right: English translation)

The results of this study indicate that the use of metacognitive scaffolding-based student worksheets not only improves students' argumentation skills but also assists them in managing their thinking processes in a conscious and structured manner. The implementation of these Student Worksheets encourages active student engagement during the learning process in making claims, gathering evidence, and performing scientific reasoning. These findings align with research by Fauzi et al (2020), which revealed that the metacognitive scaffolding approach can enhance students' reasoning and argumentation. Additionally, Mulyasari et al (2020) stated that the implementation of Student Worksheets as interactive materials can facilitate the development of

argumentation skills. The improvement in argumentation skills in this study is evident in the students' ability to formulate relevant claims, present evidence based on observations, and link claims and evidence through scientific reasoning. This aligns with the argumentation framework proposed by McNeill and Martin (2010), which states that a strong argument must contain interconnected elements of claim, evidence, and reasoning. Consequently, the results of this study demonstrate a significant effect of metacognitive scaffolding-based Student Worksheets on the argumentation skills of junior high school students in science learning.

4. Conclusion

This study demonstrates that the implementation of metacognitive scaffolding-based student worksheets led to a significant improvement in junior high school students' argumentation skills following the intervention. Specifically, the study focused on embedding metacognitive scaffolding components into the worksheets, where learning activities were aligned with the Claim, Evidence, and Reasoning (CER) framework to support structured and meaningful learning. The integration of metacognition with scaffolding strategies facilitates students in regulating and reflecting upon their thinking processes, thereby producing arguments that are are structured, logical and grounded in scientific theory. However, a key limitation of this study lies in the relatively short duration of the intervention, which limited the assessment of the long-term retention of argumentation skills. Consequently, future research is recommended to conduct long-term studies to evaluate the sustainability of these skills.

Author Contributions

All authors have equal contributions to the paper. All the authors have read and approved the final manuscript.

Funding

No funding support was received.

Declaration of Conflicting Interests

The author declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Data Availability

The datasets generated during and/ or analyzed during the current study are available from the corresponding author on reasonable request.

Declaration on AI Use

The authors declare that no artificial intelligence (AI) or AI-assisted tools were used in the preparation of this manuscript.

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