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Designing Metacognitive Scaffolding Based on Science Talk to Enhance Students Scientific Argumentation

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Abstract

Scientific argumentation is essential for critical thinking and evidence-based reasoning in 21st-century science education. However, procedural teaching methods often neglect metacognitive regulation in argument construction. This study aims to analyze the validity, practicality, and effectiveness of student worksheets designed as operational representations of science talk-based metacognitive scaffolding. Employing a Research and Development (R&D) approach with the ADDIE model (Analyze, Design, Develop, Implement, Evaluate), the research involved Grade 7E students at SMP Negeri 2 Panti, Jember. Data were gathered through expert validation, observation, pretest-posttest assessments, and student questionnaires. Results demonstrated high validity (95.5%) and practicality (95.5%). Effectiveness was evidenced by a moderate N-gain score of 0.67 and a 93.0% positive student response rate. These findings suggest that integrating metacognitive scaffolding and dialogic pedagogy significantly enhances students' scientific argumentation skills. This research contributes to the theoretical framework of argumentative learning design and metacognitive regulation in science education.

How to Cite

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INTRODUCTION

Scientific argumentation is an essential skill that students must possess in 21st-century learning, as it effectively fosters critical thinking skills (Osborne, 2010). Argumentation can bridge conceptual understanding with authentic scientific practices (Halimah et al., 2020). By engaging in scientific argumentation, students are able to state a claim, support their statements with relevant data or evidence, and provide reasoning that scientifically connects the evidence to the claim (Akili et al., 2022). Furthermore, argumentation serves as a form of expressing opinions aimed at influencing others to act accordingly, supported by evidence that justifies the argument logically and is based on scientific facts (Toulmin, 2003). Scientific argumentation skills can be cultivated through the Claim, Evidence, and Reasoning (CER) framework developed (Christoforaki et al., 2026). A claim is a statement or answer that can explain a problem. Evidence refers to the scientific data or proof utilized to support the claim. Meanwhile, reasoning is the explanation used to link the evidence to the claim through scientific principles (McNeill & Martin, 2011). This framework not only helps students deepen their conceptual understanding of science but also enhances their metacognitive maturity in solving problems systematically (Dewi et al., 2025). Various studies demonstrate that structured pedagogical interventions, including specific scaffolding and inquiry-based prompts, play a crucial role in improving students' scientific argumentation. These supports help students better formulate valid claims and back them with strong reasoning across different science contexts (Hendratmoko et al., 2023; Yang et al., 2023); Zhang & Browne, 2023).

Preliminary observations and interviews conducted with a seventh-grade science teacher at SMP Negeri 2 Panti revealed that the students' scientific argumentation skills remain relatively low. This deficiency is primarily attributed to the limited opportunities provided by the teacher for students to engage in discussions and express their opinions, coupled with the reliance on conventional teaching materials whose activities do not actively train argumentation skills. Furthermore, recent research by Andriani et al., (2025), demonstrated that the scientific argumentation skills of junior high school students in science subjects are still inadequate, predominantly situated at level 1 (58.1%), where students only generate simple claims without incorporating relevant data or evidence. Similarly, a study by Fernando et al., (2024) reported low scientific argumentation skills among students, characterized by an average score of 10.60. Many students encounter difficulties in providing evidence to substantiate the claims they make. These conditions highlight the urgent need to develop teaching materials integrated with learning approaches capable of enhancing students' scientific argumentation skills.

To overcome these problems, stepwise assistance or scaffolding is required to facilitate students in understanding concepts in a more directed and structured manner. The scaffolding employed is not merely content-based assistance but is integrated with a metacognitive approach capable of bridging students in managing their thinking processes (Rusdianto et al., 2023). According to Hennecke & Bürgler, (2023), metacognition refers to an individual's awareness of their own cognitive processes and their capacity for self-regulation in achieving predetermined goals. Operationally, this metacognitive approach consists of three main stages: planning, monitoring, and evaluating (Hidayati et al., 2025). Furthermore, according to Azizah et al., (2025), the implementation of metacognitive scaffolding through reflective questions such as 'what', 'how', and 'why' serves to deepen conceptual understanding. Their study confirms that integrating this method into Student Worksheets has proven effective in improving students' argumentation skills by stimulating a more structured and reflective mindset. Although Stofiana et al., (2025) emphasize that the metacognitive scaffolding approach can support scientific argumentation skills in formulating claims, evidence, and reasoning, a gap remains in integrating it practically into teaching materials. The issue lies in the conventional teaching materials commonly used in schools, such as textbooks, which remain rigid and inadequately train students to develop scientific argumentation skills (Dawson & Carson, 2020). Student activities in these conventional materials are largely content-heavy and do not specifically direct students toward problem-solving processes or scientific discussions. Papaioannou et al., (2023) reveal that conventional teaching materials merely present knowledge as an informative final product, lacking interactive spaces for students to engage in discussion. Students' reliance on procedural instructional formats leaves them unaccustomed to formulating claims, connecting evidence, and expressing logical reasoning (Muslim et al., 2024). Therefore, innovative teaching materials capable of bridging students to practice scientific argumentation skills are deemed highly necessary.

Consequently, this research focuses on developing an innovative teaching material termed "Science Talk". Science Talk is an advancement of the Student Worksheets specifically designed to facilitate active student involvement during learning, provide space for discussion, and train students in scientific argumentation. As a teaching material containing metacognitive questions and scaffolding assistance, Science Talk has the potential to enhance students' scientific argumentation skills by training them to make claims to solve problems, incorporate evidence to support these claims, and provide reasoning by linking the evidence to the claims through scientific explanations. Therefore, metacognitive scaffolding-based Science Talk can serve as a practical solution to improve junior high school students' scientific argumentation skills in science learning.

Previous studies have consistently highlighted the importance of developing innovative teaching materials to foster the quality of students' scientific argumentation. Research by Fitria et al., (2025) demonstrated that the use of an Argument-Driven Inquiry (ADI) and STEM-based E-LKPD effectively improved students' scientific argumentation skills within a high category. Similar research conducted by Kinanthi & Azizah (2025) also showed that utilizing an ADI-based Student Worksheets could enhance students' scientific argumentation skills. Nevertheless, these studies primarily emphasized the use of innovative materials based on ADI and STEM. To date, there is a scarcity of research highlighting the use of innovative teaching materials that explicitly apply a metacognitive scaffolding approach to enhance students' scientific argumentation skills in the science learning process. Thus, this research is necessary to fill the existing gap by focusing on the development of metacognitive scaffolding-based Science Talk. The objective of this research is to describe the validity, practicality, and effectiveness of metacognitive scaffolding-based Science Talk in improving junior high school students' scientific argumentation skills in science learning.

METHOD

Type of Research

This study is a Research and Development (R&D) project employing the ADDIE model, which consists of five stages: analysis, design, development, implementation, and evaluation (Branch, 2009).

Participants

The participants in this study were 28 students from class VII E at SMP Negeri 2 Panti, Jember, East Java, Indonesia. The participants were selected using a purposive sampling method. This method was chosen based on the school's accessibility and permission to conduct research within that specific class.

Research Procedure

The research procedure followed the ADDIE model, encompassing five stages as illustrated in Figure 1.

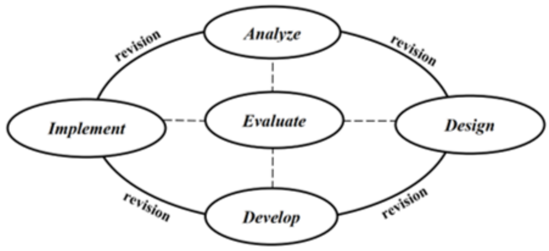

Figure 1. ADDIE Model (Branch, 2009)

The first stage is Analysis, where the researcher conducted observations and interviews to analyze science learning issues at the school. This phase included curriculum analysis, student character analysis, and needs analysis. The objective was to obtain relevant information and data to serve as the foundation for product development. The second stage is Design, involving the selection of relevant instructional materials, determining learning objectives based on the Kurikulum Merdeka teaching modules used at the school, and designing learning concepts or activities for the developed product based on the analysis results. The learning activities focused on Grade VII science topics, specifically Temperature, Heat, and Expansion.

The third stage is Development, which included material compilation and the creation of the "Metacognitive Scaffolding Based on Science Talk" teaching materials. At this stage, the researcher also developed research instruments and performed product validation and revision. Validation was conducted by three expert validators, comprising two science education lecturers and one science teacher. Following the validation and revision process, the researcher proceeded to the implementation phase. The fourth stage is Implementation, where the researcher conducted learning sessions using the developed product in the classroom. This stage aimed to test whether the product influenced students' scientific argumentation and to assess the practicality and effectiveness of the product during the learning process.

The fifth stage is Evaluation, conducted to assess the quality and effectiveness of the product. The evaluation process was carried out comprehensively, covering all phases from analysis to implementation. The purpose of this evaluation was to obtain assessment results and a final conclusion regarding the developed product in accordance with the research objectives.

Research Instruments

This study utilized primary and secondary data to obtain a comprehensive overview of the development and implementation of the learning product. Primary data were obtained directly from the development and implementation phases, encompassing validity, practicality, effectiveness, and student responses. Validity data were collected through product validation techniques using expert validation sheets to assess the suitability and quality of the developed product. Practicality data were gathered through classroom observations using learning implementation sheets to evaluate the extent to which the product could be applied effectively and efficiently in a classroom context. Effectiveness data were collected through scientific argumentation skill tests in the form of pretests and post-tests using specific assessment sheets, as well as through student response questionnaires to evaluate students' perceptions, experiences, and acceptance levels of the developed product. Furthermore, secondary data were obtained to strengthen the analysis and provide empirical context for science learning. these included interview results regarding learning challenges at the school collected through interview and observation techniques as well as documentation in form of photographs, videos, and field notes generated during research process.

Data Analysis

This study employed both qualitative and quantitative data analysis techniques. Qualitative data analysis was conducted to comprehensively describe the results of the product development process specifically the analyze, design, and develop phases to yield a product suitable for use as instructional material in the classroom. Meanwhile, quantitative data analysis was performed to describe the results of the validity, practicality, and effectiveness tests of the developed product. The formula used to analyze the validity level of the science talk-based metacognitive scaffolding.

$$V = \frac{\sum x}{\sum xi}\ x\ 100\%$$

Where V is the validity percentage, $\sum x$ is the total score obtained, and $\sum x_i$ is the maximum total score. The criteria for the validity level are presented in Table 1.

Table 1. Validity Criteria

Percentage of Achievement (%)	Validity Level
25 – 45	Invalid
46 – 65	Less Valid
66 – 85	Fairly Valid
86 – 100	Highly Valid

(Putri et al., 2024)

The formula used to calculate the practicality level of the science talk-based metacognitive scaffolding is as follows:

$$P = \frac{\sum TSe}{\sum TSh}\ x\ 100\%$$

Where P is the practicality percentage, $\sum TSe$ is the total score obtained, and $\sum TSh$ is the maximum total score. The criteria for the product's practicality are presented in Table 2.

Table 2. Practicality Criteria

Percentage of Achievement (%)	Practicality Level
25 – 45	Impractical
46 – 65	Less Practical
66 – 85	Fairly Practical
86 – 100	Highly Practical

(Putri et al., 2024)

The formula used to calculate effectiveness through the scientific argumentation skills test, administered as student pre-tests and post-tests, is presented below:

$$n = \frac{posttest\ score - pretest\ score}{\max score - pretest\ score}$$

The assessment criteria for students' scientific argumentation skills, based on the calculated N-gain score, can be seen in Table 3.

Table 3. N-Gain Criteria

N-Gain	Criteria
$g \geq 0.7$	High
$0.3 \leq g < 0.7$	Medium
$g < 0.3$	Low

(Hake, 1998)

The product's effectiveness was also determined through a student response questionnaire, which was calculated using following formula:

$$RS = \frac{A}{B}\ x\ 100\%$$

Where RS is student response, A is total score obtained, and B is maximum score. The criteria for the student response questionnaire are presented in Table 4.

Table 4. Student Response Questionnaire Scores

Student Response Score	Category
25 – 45	Poor
46 – 65	Fair
66 – 85	Good
86 – 100	Very Good

(Putri et al., 2024)

RESULT AND DISCUSSION

The first phase of the product evelopment research began with the analyze phase. This phase was conducted through observations and interviews with science teachers to obtain preliminary information regarding the learning process, which served as the foundation for the study. The interview results regarding the curriculum analysis indicated that learning at the school implemented the Kurikulum Merdeka (Independent Curriculum) across all grade levels. Consequently, all learning activities in the developed product were aligned with learning achievements and learning objectives specified in Kurikulum Merdeka.

Furthermore, results of student character analysis revealed that students frequently felt bored and disengaged during the learning process. The student needs analysis showed that learning process remained teacher-centered and still relied on conventional instructional materials, specifically government-issued textbooks. This condition resulted in students being undertrained in critical thinking and communication, leading to relatively low scientific argumentation skills. Therefore, there is a need for innovative instructional materials capable of improving students' scientific argumentation skills in science learning.

The subsequent phase was the design phase, where the researcher designed the development product based on the findings from the analyze phase, ensuring that the resulting product aligned with the intended development goals. The design process began by determining the science learning materials, namely temperature, heat, and thermal expansion, setting the learning objectives, designing learning activities in accordance with the indicators of scientific argumentation skills using the CER framework, and aligning them with the metacognitive scaffolding approach. Following this, the researcher proceeded to the develop phase. In this phase, the researcher created the metacognitive scaffolding-based Science Talk based on the previous phases. Once the initial product was formed, an expert validation test was conducted by expert validators. This validation test aimed to obtain feedback and suggestions. The researcher then revised the product based on the validators' comments and suggestions to ensure that the developed product was feasible for classroom implementation.

Figure 2. Content of the metacognitive scaffolding based on Science Talk and students' scientific argumentation skills

The metacognitive scaffolding based on Science Talk was developed by integrating patterns of argumentation skill indicators, which consist of three indicators: claim, evidence, and reasoning (CER). Additionally, student activities within the Science Talk combine three main components of the metacognitive approach planning, monitoring, and evaluating which are supplemented with scaffolding to help solve problems.

Validity of Metacognitive Scaffolding based on Science Talk

The validity test was conducted using a validation sheet that encompassed the assessment of format, language, content, and graphical design aspects (Muliana et al., 2025). The product validation results are presented in Table 5.

Table 5. Validation Results of Science Talk-Based Metacognitive Scaffolding

Assessment Aspect	Validator (%)			(%)	Category
	V1	V2	V3		
Format Aspect	96	96	100	97.2	Highly Valid
Language Aspect	96	88	92	91.7	Highly Valid
Content and Material Aspect	93	96	100	96.4	Highly Valid
Graphics Aspect	100	95	95	96.7	Highly Valid
Average	96.1	93.7	96.7	95.5	Highly Valid

Based on Table 5, the validation results achieved an average score of 95.5%, categorized as highly valid. This indicates that the developed product has met both the conceptual and technical feasibility standards required for use in the learning process to assess students' scientific argumentation skills. However, the language aspect received the lowest percentage compared to the other evaluated aspects. This was primarily because the language used in the Science Talk-based metacognitive scaffolding was insufficiently connected to students' daily lives, thereby making the material difficult to comprehend. Consequently, revisions were made in accordance with the validators' suggestions and feedback to ensure the product's readiness for the implementation phase. This aligns with Ridho et al., (2020), who stated that a developed product is declared valid by expert validators if it satisfies the structural requirements, including content and language feasibility, material presentation, and practical utility as instructional material.

Practicality of Metacognitive Scaffolding Based on Science Talk

The practicality of the developed product was determined using an instructional implementation observation sheet. This instrument aimed to assess ease of implementing product during learning activities. The assessment was conducted by three observers across six meetings, with each session lasting 2x40 minutes. The practicality results of product are presented in Table 6.

Table 6 shows that the implementation of learning using the metacognitive scaffolding based on Science Talk obtained an average score of 95.5%, categorized as highly practical. This result indicates that the sequence of learning activities presented in the developed product was easy for students to follow. Vitoria et al., (2018) stated that a product is considered practical if its implementation is effective and easily followed by students during the learning process. Furthermore, according to (Hasanah et al., 2022), if the practicality score falls between 86% and 100%, the developed product can be categorized as highly practical. However, during its implementation, the researcher encountered several challenges in the learning process. Specifically, during the first meeting, students experienced difficulties in understanding the learning activities (questions) based on the scientific argumentation framework (CER), as well as the presentation format of the provided scaffolding.

Table 6. Learning Implementation Results

Assessed Activity	Observer Percentage			(%)	Category
	O1	O2	O3		
Students access the Science Talk-based metacognitive scaffolding	100.0	100.0	100.0	100.0	Highly Practical
Students pay attention to the teacher's explanation	87.5	95.8	95.8	93.1	Highly Practical
Students read the science phenomenon and answer the claim questions	93.8	100.0	100.0	97.9	Highly Practical
Students form groups	100.0	100.0	100,0	100,0	Highly Practical
Students conduct practical activities	87.5	93.8	93.8	91.7	Highly Practical
Students present the data (evidence)	93.8	100.0	87.5	93.8	Highly Practical
Students answer the reasoning and evaluation questions	100.0	87.5	100.0	95.8	Highly Practical
Students draw conclusions and present the results	87.5	91.7	95.8	91.7	Highly Practical
Overall Average	93.8	96.1	96.6	95.5	Highly Practical

To address this, the researcher provided additional verbal and visual explanations regarding the purpose of the student activities and the scaffolding to facilitate better comprehension. Another challenge arose during the experimental phase, where some students remained passive within their groups. Consequently, the researcher implemented a role-rotation system for each group member to ensure that all students could participate actively during the learning activities.

Effectiveness of Metacognitive Scaffolding-Based on Science Talk

The effectiveness of the developed product was assessed using a scientific argumentation skills test in the form of a pretest and posttest. This test was utilized to determine the differences in students' learning outcomes before and after the intervention of the metacognitive scaffolding-based Science Talk. The analysis results of the scientific argumentation skills test are presented in Table 7.

Table 7. Pretest-Posttest Analysis Results of Scientific Argumentation Skills

Indicator	Mean		N-Gain	Category
	Pretest	Posttest		
Claim	47.9	92.0	0.85	High
Evidence	31.8	80.1	0.71	High
Reasoning	12.5	52.1	0.45	Medium
Average	30.8	74.7	0.67	Medium

Table 7 shows an improvement in students' scientific argumentation skills before and after the intervention, obtaining an average N-gain score of 0.67, which is categorized as moderate. This improvement is attributed to the implementation of the metacognitive scaffolding-based Science Talk, in which the learning activities follow the Claim, Evidence, and Reasoning (CER) framework. The synergy between these components is central to the intervention's success. While metacognitive scaffolding provides explicit cognitive prompts that foster internal self-reflection, Science Talk bridges this process by creating a social environment where students can openly articulate, debate, and sharpen their reasoning with peers.

The data analysis of the Claim indicator obtained an N-gain score of 0.85, categorized as high. In this indicator, the majority of the students were able to formulate clear, specific claims relevant to the concepts being studied. Student activities for the Claim indicator were designed by initially providing a stimulus to trigger a response in communicating ideas and to open a space for student discussion. The provided stimulus was in the form of scientific phenomena found in everyday life. For example, students read a science phenomenon related to hot and cold water temperatures. Based on this phenomenon, students were asked to formulate a specific claim, with a prompt such as, "Make an initial claim (opinion) regarding the temperature of hot water compared to cold water". During the classroom intervention, this phase unfolded dynamically. Initially, students tended to express intuitive but unscientific opinions based on their prior thoughts. However, through Science Talk, peer questioning prompted them to actively evaluate their own initial ideas (metacognitive planning), leading to the collaborative refinement of their claims before formally writing them down. ." Learning activities that begin with presenting a scientific phenomenon followed by formulating a claim ensure that the students' answers are grounded in observations (Fitria et al., 2025). Consequently, this activity stimulates higher-order thinking skills, fosters students' metacognitive abilities in articulating ideas to answer initial questions relevantly, and serves as a foundation for constructing subsequent scientific arguments (Siswati et al., 2025).

The analysis of the Evidence indicator yielded an N-gain score of 0.71, categorized as high. The Evidence indicator activities in the metacognitive scaffolding-based Science Talk were designed sequentially, following the previous activities. After reading the science phenomenon regarding hot and cold water temperatures as a basis for claim formulation, students were asked to conduct an experiment to obtain data for testing the claim. An example activity for the Evidence indicator is: "Conduct the temperature measurement experiment. Record the measurement results in the observation table!" This activity ensures that students generate real data or evidence through scientific experiments. Cognitively, the transition from formulating a claim to gathering evidence forced students to engage in metacognitive monitoring continuously checking whether their gathered experimental data was accurate and aligned with their initial claim. During the Science Talk sessions, students frequently debated the validity of their temperature measurements, which shifted their focus from merely completing the worksheet to actively monitoring and verifying their findings. This process effectively develops their metacognitive awareness in monitoring the accuracy of the data used as evidence (Omarchevska et al., 2022; Fakhriyah et al., 2022).

The analysis of the Reasoning indicator achieved an N-gain score of 0.45, falling into the moderate category. The Reasoning indicator activities in the metacognitive scaffolding-based Science Talk were also designed sequentially. In this indicator, students were required to explain why the evidence supports their formulated claim. An example prompt for this indicator is: "Explain the scientific reason why your experimental results (evidence) regarding the temperature measurements of hot and cold water support the claim you made!". This activity aimed to bridge students' empirical observations with conceptual assertions. However, the reasoning indicator obtained the lowest N-gain score compared to the other argumentation indicators.

This outcome highlights a critical cognitive challenge inherent in scientific reasoning; unlike formulating claims or identifying isolated evidence, constructing a logical justification demands a high level of abstraction that frequently induces an overwhelming intrinsic cognitive load (Gkintoni et al., 2025). From the perspective of metacognitive theory, this difficulty signifies a deficit in students' metacognitive monitoring and self-regulation when navigating complex cognitive tasks (Wang et al., 2023). Although the majority of students successfully managed lower-order cognitive demands (stating claims and identifying data), they struggled to activate high-order metacognitive processing to evaluate how well their conceptual knowledge integrated with empirical evidence (Guamanga et al., 2025). This finding indicates that students are not yet accustomed to using metacognitive strategies to monitor their own explanatory gaps or self-correct logical inconsistencies during argument construction (Rivas et al., 2022). Consequently, the moderate improvement underscores that while Science Talk provided a structured framework, the accompanying metacognitive scaffolding must be made more explicit and adaptive to systematically reduce the cognitive friction encountered by students during the reasoning process, thereby enhancing their capacity to evaluate the accuracy and validity of their arguments (Dewi et al., 2025).

These findings offer significant pedagogical implications for science teachers. The study highlights that implementing interactive discussions alone is inadequate without explicit cognitive guidance. Educators must actively integrate structured metacognitive frameworks (such as the CER framework) into their worksheets to systematically guide student discourse. By transforming the classroom culture from teacher-centered explanations to student-led scientific argumentation via structured Science Talk, teachers can effectively foster students' conceptual mastery of scientific topics alongside their critical reasoning abilities.

Table 8. Results of the Student Response Questionnaire

Aspect	Percentage (%)	Category
Interest	93.2	Very Good
Material	94.1	Very Good
Language	91.8	Very Good
Average	93.0	Very Good

The effectiveness of the metacognitive scaffolding based on Science Talk was measured not only through the scientific argumentation skills test results but also using a student response questionnaire. The instrument was administered as a questionnaire sheet containing positive and negative statements regarding the use of the metacognitive-based Science Talk during the learning process. The student response questionnaire was distributed after posttest. The assessment of student responses consisted of three aspects: interest, material, and language. The results ofstudent response questionnaire are presented in Table 8.

Table 8. shows that the student responses obtained an average score of 93.0, categorized as Very Good. All assessment aspects also received an Very Good category. Hariyati & Rachmadyanti, (2022) state that student response questionnaires serve as a source of feedback following the learning process. If a developed product achieves a high average score, it can be considered effective for use in learning activities. Thus, the positive responses provided by the students indicate that the metacognitive scaffolding-based Science Talk is easily understood and can be utilized effectively by students (González-Howard & McNeill, 2019). Based on the discussion presented in this study, the developed product meets the criteria of being valid, practical, and effective, and it is capable of enhancing students' understanding of the studied material. Teaching materials are deemed high quality if they fulfill the criteria of validity, practicality, and effectiveness (McKenney & Reeves, 2021). Therefore, it can be concluded that the metacognitive scaffolding-based Science Talk is highly feasible and suitable for use as teaching material in science classrooms.

Limitations of the Study

Although this study confirms the effectiveness of science talk-based metacognitive scaffolding in enhancing students' scientific argumentation skills, several limitations must be acknowledged. First, during the initial phase of implementation, some students tended to be passive and experienced disorientation when adapting to the metacognitive prompts, primarily due to their strong reliance on conventional learning methods (Marthaliakirana et al., 2022). Second, the scope of this research was confined to a single junior high school with a restricted sample size, which may limit the generalizability of the findings. Finally, the relatively short duration of the intervention implies that the long-term retention of the students' argumentation skills could not be comprehensively evaluated (Probosari et al., 2019). Therefore, future research should consider expanding the sample size across multiple schools, extending the intervention period, and providing an adequate preliminary phase to familiarize students with metacognitive scaffolding prior to the primary data collection.

CONCLUSION

Based on the research findings, it can be concluded that the development of the metacognitive scaffolding-based on Science Talk is proven to be highly valid, practical, and effective in improving students' scientific argumentation skills based on the Claim, Evidence, Reasoning (CER) framework. The primary contribution of this study proves that integrating metacognitive scaffolding into dialogic teaching materials transforms the function of worksheets from mere procedural instructional tools into instruments for cognitive regulation. This approach comprehensively facilitates students in planning, monitoring, and evaluating their thinking structures to construct arguments independently and systematically. Although this intervention has proven to guide students exceptionally well, the highest cognitive challenge remains in the reasoning formulation phase. Therefore, future research is recommended to develop and explore more explicit and structured metacognitive scaffolding designs to facilitate the reasoning process, specifically focusing on pedagogical strategies that assist students in profoundly linking the validity of evidence with relevant scientific concepts or principles. On a broader theoretical level, this integrated framework enriches the science education literature by bridging social constructivist discourse with self-regulated cognitive theories. It provides a foundational paradigm demonstrating that cultivating authentic scientific literacy requires combining collaborative peer interaction and internal cognitive regulation.

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