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Enhancing Scientific Literacy on Global Warming in Junior High School: The Role of SETS-Oriented Guided Inquiry and Infographic-Based Multimedia

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Abstract
Scientific literacy in the context of global warming remains a persistent challenge in science learning, particularly in students' ability to interpret data and use evidence for decision-making in real-world contexts. This study aimed to examine the effect of a SETS (Science, Environment, Technology, and Society)-oriented Guided Inquiry Learning model supported by infographic-based multimedia on students' scientific literacy. The research was conducted at SMP Negeri 52 Surabaya with 30 seventh-grade students during the 2025/2026 academic year on the topic of global warming. A pre-experimental one-group pretest–posttest design was employed to investigate changes in students' scientific literacy before and after the implementation of the learning model. The intervention was carried out over four weeks in eight instructional sessions. Data were collected through validated multiple-choice and essay-based pretests and posttests and were analyzed using N-Gain and paired-samples t-test. The results indicated a statistically significant improvement in students' scientific literacy ($p < .05$) with an average N-gain of 0.53 (medium category). These findings suggest that integrating SETS-oriented guided inquiry learning with infographic-based multimedia can enhance students' engagement and support the development of scientific literacy, particularly in understanding complex environmental issues such as global warming.

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INTRODUCTION

Entering the 21st century, rapid advances in science and technology have intensified the need for high-quality science education that equips students not only with knowledge but also with reasoning and problem-solving skills. However, contemporary science education is increasingly evaluated based on its ability to develop scientific literacy, defined as students' competence to explain phenomena scientifically, evaluate and design inquiry, and interpret evidence for decision-making in real-world contexts (OECD, 2019; OECD, 2023a). This conceptualization positions scientific literacy as an integration of knowledge, practices, and contextual application, making it a critical benchmark for preparing students to address complex global issues such as climate change.

Despite its importance, international assessments reveal that Indonesian students' scientific literacy remains a persistent concern. In PISA 2018, Indonesia's science score was 396, and in PISA 2022 it declined to 383, far below the OECD average of 485 (NCES, 2024). Only 34% of Indonesian students achieved at least Level 2 proficiency, compared to 76% across OECD countries, indicating that most students struggle to apply scientific knowledge in meaningful contexts (OECD, 2023b). This gap suggests not merely low achievement but a systemic instructional issue, where science learning is still dominated by content transmission

rather than competence-oriented approaches that foster reasoning, inquiry, and contextual understanding (Kemendikbudristek, 2023).

Findings from TIMSS further confirm these challenges at earlier stages of education. Indonesia's Grade 4 science score in TIMSS 2015 was 397, significantly below the international benchmark of 500, indicating limited conceptual understanding and application skills. At the local level, a preliminary diagnostic assessment conducted on 30 September 2025 in a junior high school in Surabaya revealed that more than half of students in one Grade VII class were categorized as having low scientific literacy. This pattern highlights a critical need for instructional strategies that not only improve conceptual understanding but also support students in reasoning with evidence and applying knowledge to socio-scientific issues such as global warming.

One key challenge in learning about global warming lies in its cognitive complexity. The topic requires students to integrate abstract scientific concepts, interpret data trends, and connect scientific explanations with environmental, technological, and societal implications. Traditional guided inquiry approaches, while effective in promoting active learning, often focus primarily on procedural inquiry skills without sufficiently addressing the contextual and interdisciplinary nature of such issues. Therefore, a more integrative pedagogical approach is required to bridge conceptual understanding, inquiry processes, and real-world relevance.

In this context, the Science, Environment, Technology, and Society (SETS) orientation provides a critical conceptual framework that complements guided inquiry. The SETS approach situates scientific concepts within authentic socio-environmental contexts, enabling students to understand the interconnections between scientific knowledge, technological development, environmental issues, and societal impacts. When combined with guided inquiry, SETS provides the contextual dimension that supports meaningful problem framing, while inquiry processes facilitate evidence-based reasoning. Furthermore, infographic-based multimedia can serve as cognitive support by simplifying complex information, visualizing data relationships, and reducing cognitive load, thereby enhancing students' comprehension of abstract climate-related concepts.

Recent international studies have attempted to improve scientific literacy in climate education through various approaches. For example, inquiry-based climate learning has been shown to enhance students' reasoning skills but often lacks strong contextual integration (e.g., studies published between 2022–2024). Context based and socio-scientific issue approaches have improved students' engagement and relevance perception but sometimes fall short in developing structured inquiry skills. Meanwhile, multimedia supported learning has demonstrated effectiveness in improving conceptual understanding but does not inherently promote inquiry or critical reasoning. These findings indicate that treating inquiry, context, and media as separate components limits their overall effectiveness in addressing the multidimensional demands of scientific literacy in global warming education.

Therefore, the key gap is not merely the limited number of studies combining these approaches, but the lack of a pedagogically integrated model that aligns context (SETS), process (guided inquiry), and cognitive support (infographic multimedia) to address the specific cognitive and epistemic challenges of learning about global warming. This integrated approach is theoretically expected to enhance students' ability to connect concepts, engage in inquiry, and interpret evidence within meaningful real-world contexts. Based on this rationale, the present study aims to investigate the effectiveness of SETS-oriented Guided Inquiry Learning supported by infographic-based multimedia in improving Grade VII students' scientific literacy, particularly within the competency domain, on the topic of global warming in a junior high school context in Surabaya.

METHODS

Research Design Justification

This study employed a quantitative approach using a pre-experimental design to examine the effect of an instructional intervention on students' scientific literacy. Specifically, a One-Group Pretest–Posttest design was applied, in which a single group of students was measured before and after the intervention. Students completed a pretest to assess baseline scientific literacy, followed by the implementation of the instructional treatment, and subsequently a posttest to measure learning outcomes. The difference between pretest and posttest scores was used to determine the extent of change following the intervention (Sugiyono, 2023).

The use of a pre-experimental design was based on contextual constraints, including limited access to equivalent comparison groups and school policies that did not permit random assignment. While this design is appropriate for preliminary investigation in natural classroom settings, it has inherent limitations in internal validity. Potential threats include maturation, testing effects, and history effects, which may influence the observed outcomes. Therefore, the findings should be interpreted with caution, particularly in terms of causal inference.

The study was conducted during the second semester of the 2025/2026 academic year at SMP Negeri 52 Surabaya. The population consisted of approximately 120 seventh-grade students distributed across seven classes. The sample was selected using purposive sampling, with Class VII-E chosen based on preliminary diagnostic assessment results indicating the lowest level of scientific literacy among the cohort. The final sample comprised 30 students aged 12–13 years, with a relatively balanced gender distribution. Although purposive sampling may introduce selection bias, it was employed to target a group requiring instructional intervention.

The instructional intervention, consisting of SETS (Science, Environment, Technology, and Society) oriented Guided Inquiry Learning supported by infographic-based multimedia, was implemented over four weeks in eight instructional sessions. The independent variable was the instructional treatment, while the dependent variable was students' scientific literacy. Scientific literacy was measured using a test instrument comprising multiple-choice and essay items aligned with scientific competence indicators.

Ethical procedures were observed prior to data collection. Approval was obtained from the school administration, and informed consent was secured from students and their parents or guardians. Participants were informed about the purpose of the study, and confidentiality of their responses was maintained.

Data analysis involved descriptive and comparative techniques, focusing on differences between pretest and posttest scores to evaluate changes in students' scientific literacy following the intervention. While this approach allows for identifying improvement trends, future studies employing quasi-experimental or randomized controlled designs are recommended to strengthen the validity of causal claims.

Validity of Scientific Literacy Instrument

The instructional materials and research instruments were validated by two science teachers from SMP Negeri 52 Surabaya. The validation results indicated that all instructional materials and instruments met the feasibility standards and were deemed valid for use. A test is defined as a set of questions designed to measure and evaluate an individual's or group's abilities, skills, knowledge, and potential.

In this study, a test instrument was used to assess students' scientific literacy skills in order to obtain data on the improvement of their scientific literacy in science learning through the

implementation of SETS-oriented Guided Inquiry Learning on the topic of global warming. The test consisted of 8 multiple-choice items and 4 essay questions. All items were developed based on scientific literacy indicators within the scientific competence domain.

The multiple-choice items were scored using a dichotomous scheme, with a score of 5 assigned for correct answers and 0 for incorrect answers. Meanwhile, the essay items were evaluated using a rubric with a score range of 0–10. A score of 0 was assigned when no response was provided; a score of 1 was given for incorrect answers or responses that failed to provide appropriate decisions or actions; scores of 2–4 were assigned for partially correct answers that mentioned decisions or actions but were not fully aligned with the question; scores of 5–7 were given for correct answers that identified at least two appropriate decisions or actions but lacked explanation; and scores of 8–10 were assigned for complete and accurate responses that included at least three appropriate decisions or actions supported by clear and correct explanations.

Data Analysis Techniques

Data analysis was carried out quantitatively using SPSS 2.01 version statistical software. The stages of data analysis included:

Test of Normality

The normality test was conducted using the Shapiro–Wilk test with the assistance of SPSS Statistics software (version 21.0) at a 95% confidence level ($\alpha = 0.05$). The analysis of normality in SPSS output was based on the Test of Normality table, where the Kolmogorov–Smirnov test is used for sample sizes greater than 50, while the Shapiro–Wilk test is applied for sample sizes of 50 or fewer. The hypotheses tested were as follows: H_0: the data are normally distributed, and H_1: the data are not normally distributed. The data are considered to be normally distributed if the significance value is greater than α (0.05), indicating that H_0 is accepted; conversely, if the significance value is less than or equal to α (0.05), H_0 is rejected, indicating that the data are not normally distributed.

Paired Sample t-test

If the data are found to be normally distributed, further analysis can be conducted using parametric statistical methods. In this study, the statistical test employed was the dependent sample t-test (paired-samples t-test), which is used to compare the means of two related data sets. This test enables the analysis of differences between pretest and posttest scores within the same group, where each subject is measured under both conditions (Syafriani et al., 2023). The hypotheses tested were as follows: H_0: there is no significant difference in students' scientific literacy before and after the implementation of guided inquiry learning; and H_1: there is a significant difference in students' scientific literacy before and after the implementation of guided inquiry learning. The t-test was conducted at a significance level of 0.05, with the following decision criteria: if the sig. (2-tailed) value is greater than α (0.05), H_0 is accepted and H_1 is rejected; conversely, if the sig. (2-tailed) value is less than α (0.05), H_0 is rejected and H_1 is accepted.

N-Gain Analysis

To analyze the improvement in students' scientific literacy, the pretest and posttest results were evaluated using N-Gain analysis with SPSS 21.0 version. The N-Gain score was obtained by calculating the difference between the posttest and pretest scores and then comparing it with the difference between the maximum possible score and the pretest score. Mathematically, the formula is as follows.

$$N\text{-}Gain\ Score = \frac{Sposttest - Spretest}{Smaks - Spretest}$$

After the calculation, the N-gain score is interpreted based on specific categories to assess the magnitude of the improvement.

Table 1. Normalized Gain Categories

N-Gain Value	Categories
$(N-Gain) < 0{,}30$	Low
$0{,}70 > (N-Gain) \geq 0{,}30$	Medium
$(N-Gain) \geq 0{,}70$	High

This study employed a test instrument to measure students' scientific literacy skills in order to obtain data on the improvement of students' scientific literacy in science learning through the implementation of a SETS-oriented guided inquiry learning model on the topic of global warming. The test consisted of 8 multiple-choice items and 4 essay items. All items were developed based on scientific literacy indicators within the scientific competence domain.

RESULTS AND DISCUSSION

The study was conducted in the second semester of the 2025/2026 academic year at SMP Negeri 52 Surabaya, with Class VII-E serving as both the research subjects and the sample. The research was implemented in a single class through a sequence of activities consisting of a pretest, two instructional meetings, and a posttest. Prior to implementation, the instructional materials and research instruments underwent a validation process by two teachers. The validation results indicated that all instructional materials and instruments met the feasibility standards and were therefore deemed valid for use; a summary of the validation results is provided in the Appendix. At the initial stage, students completed a 60 minute pretest to identify their baseline scientific literacy. The intervention was then carried out over two meetings, each allocated 2 class periods (2 × 40 minutes). Instruction applied the Guided Inquiry Learning model supported by infographic-based multimedia and oriented to the SETS (Science, Environment, Technology, and Society) approach. The first meeting was held on Wednesday, 4 February 2026, and the second on Tuesday, 10 February 2026. After the treatment was completed, students took a 60-minute posttest to measure learning outcomes and changes in scientific literacy following the implementation of Guided Inquiry Learning. Upon completion of the research sequence, the collected data were analyzed to address the research questions, including pretest–posttest analysis, analysis of lesson implementation, and analysis of students' questionnaire responses regarding the applied instructional model. The results of the analysis are described as follows.

Table 1. Test of Normality with SPSS 21.0 version

	Kolmogorov-Smirnov			Shapiro-Wilk		
Posttest- Pretest	Statistic	df	Sig.	Statistic	df	Sig.
	147	30	0.98	.944	30	.115

The results of the normality test indicated that the Shapiro–Wilk significance value for the difference scores (posttest - pretest) was 0.115 ($p > 0.05$) with a W value of 0.944, suggesting that the difference data were normally distributed. Therefore, the assumption of normality was satisfied, and further analysis comparing pretest and posttest scores could be conducted using a parametric test, namely the paired-samples t-test. The results of the paired-samples t-test are presented in table 2.

Table 2. Paired Sample t-test Results

	Paired Difference					t	df	Sig.(2-tailed)
	Mean	Std.Deviation	Std.Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Pair 1 Pretest-Posttest	-35.067	10.235	1.869	-38.888	-31.245	-18.766	29	.000

Based on the results of the paired-samples t-test for Pair 1 (Pretest–Posttest), the Sig. (2-tailed) value was 0.000 ($p < 0.05$), indicating a statistically significant difference between pretest and posttest scores. The negative sign of the difference (pretest - posttest) indicates that posttest scores were higher than pretest scores, suggesting that the instructional treatment was associated with a meaningful improvement in students' scientific literacy outcomes. Furthermore, N-Gain analysis was conducted to determine the extent of improvement in students' scientific literacy. The improvement in students' scientific literacy is presented in Figure 3 below.

The results of the paired-samples t-test indicated a statistically significant difference between pretest and posttest scores ($p < 0.05$), demonstrating that the implementation of SETS-oriented Guided Inquiry Learning supported by infographic-based multimedia contributed to a meaningful improvement in students' scientific literacy. This finding is consistent with previous research showing that guided inquiry enhances students' scientific reasoning and literacy through active engagement (Wen et al., 2020). The improvement identified through N-Gain analysis further indicates that the intervention produced not only statistically significant changes but also meaningful learning gains, supporting its suitability for evaluating learning improvement in pre-experimental designs. The effectiveness of this approach can be explained by the integration of the SETS framework, which contextualizes scientific concepts within environmental, technological, and societal dimensions, thereby facilitating deeper understanding of complex issues such as global warming (Muccione et al., 2025). Additionally, infographic-based multimedia supports cognitive processing by visualizing abstract and data-intensive concepts, which enhances students' comprehension and learning outcomes (Jaleniauskienė & Kasperiunienė, 2023). This result aligns with studies indicating that multimedia-supported inquiry learning improves conceptual understanding and data interpretation skills (Agustina et al., 2020). Moreover, climate education research emphasizes that integrating inquiry with socio-scientific contexts strengthens students' ability to apply scientific knowledge in real-world situations (OECD, 2023a). The findings also suggest a synergistic effect, where inquiry provides the learning process, SETS offers contextual relevance, and multimedia delivers cognitive support, addressing the multidimensional nature of scientific literacy (OECD, 2023b). Therefore, this integrated approach is effective in enhancing students' scientific literacy, particularly in the context of global warming education.

The improvement in students' scientific literacy was analyzed using the N-Gain analysis, calculated based on the results of the pretest and posttest scores. The N-Gain analysis was performed using SPSS software (version 21.0), and the results are presented in Table 3 below.

Table 3. N-Gain analysis using SPSS 21.0 version

	N	Minimum	Maximum	Mean	Std. Deviation
N-Gain	30	.31	.86	.5290	.15388
Valid N (listwise)	30				

The descriptive statistics show N = 30, with a minimum N-gain of 0.31, a maximum of 0.86, a mean of 0.5290, and an SD of 0.15388, indicating that the improvement in scientific literacy falls within the medium category, with noticeable variation among students (Arbadilah et al., 2025). The moderate mean N-gain suggests that the instructional intervention was sufficiently effective in improving students' scientific literacy; however, the effectiveness was not evenly distributed. The gap between the minimum and maximum scores indicates variability that may be influenced not only by differences in guidance but also by students' prior knowledge and their varying levels of visual literacy in interpreting infographic-based materials. Students with stronger prior conceptual understanding are more likely to benefit from inquiry-based activities, while those with lower initial knowledge may require additional scaffolding. Similarly, differences in the ability to process visual information may affect how effectively students interpret data presented in infographics (Sholihah et al., 2023). In addition, the SETS orientation enhances the meaningfulness of learning by linking scientific concepts to environmental, technological, and societal contexts, which supports the development of scientific literacy in real-world issues such as global warming (Lestari et al., 2025). Therefore, the variation in N-gain scores reflects not only the effectiveness of the intervention but also individual differences in students' cognitive readiness and learning characteristics. The level of students' scientific literacy attainment is presented in the following figure 1.

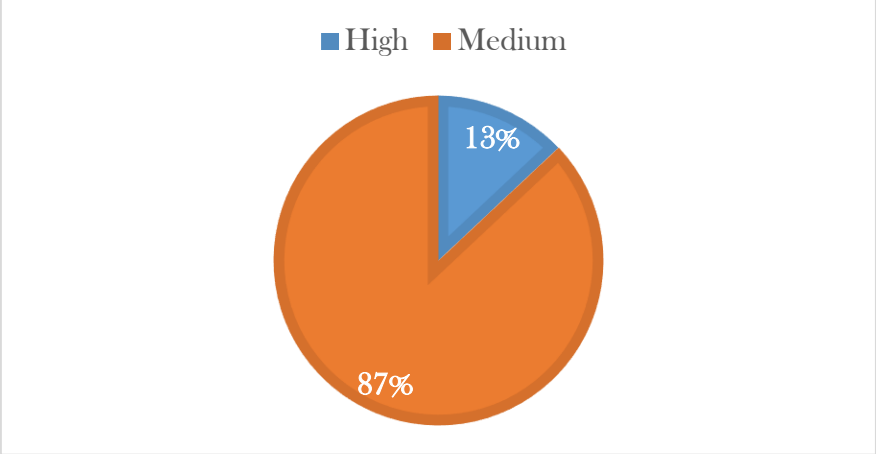


Figure 1. Percentage of N-Gain for All Students

The pie chart shows that 87% of students achieved a medium N-gain, while 13% reached a high N-gain, indicating that the intervention generally produced moderate improvement with a smaller group experiencing substantial gains. This pattern suggests that although the instructional design was effective, its impact varied across different components of scientific literacy. The medium gain can be linked to the characteristics of the infographic-based multimedia, which were particularly effective in supporting students' ability to construct and design scientific inquiry through visual representation of concepts and processes. However, the same media appeared less effective in strengthening students' ability to interpret data and evidence critically, as this competency requires deeper analytical reasoning beyond visual comprehension. This finding aligns with previous studies showing that guided inquiry can enhance procedural and conceptual

understanding when supported by structured materials (Andriani et al., 2021). Furthermore, the SETS orientation contributed to contextual understanding by connecting scientific concepts to environmental and societal issues, but its effectiveness depends on the depth of facilitation and students' ability to engage in higher-order reasoning (Puspitasari et al., 2024). Although infographic-based materials have been shown to improve scientific literacy, their optimal impact is achieved when combined with explicit scaffolding for data interpretation and evidence-based reasoning (Muhyiddin et al., 2023). Therefore, the predominance of medium gains reflects a partial success of the intervention, where visual and contextual supports enhanced certain competencies, while more complex analytical skills require further instructional reinforcement. These data were then further analyzed to examine improvements in each scientific literacy indicator within the scientific competence domain. The mean pretest and posttest scores for each indicator are presented in the following figure.

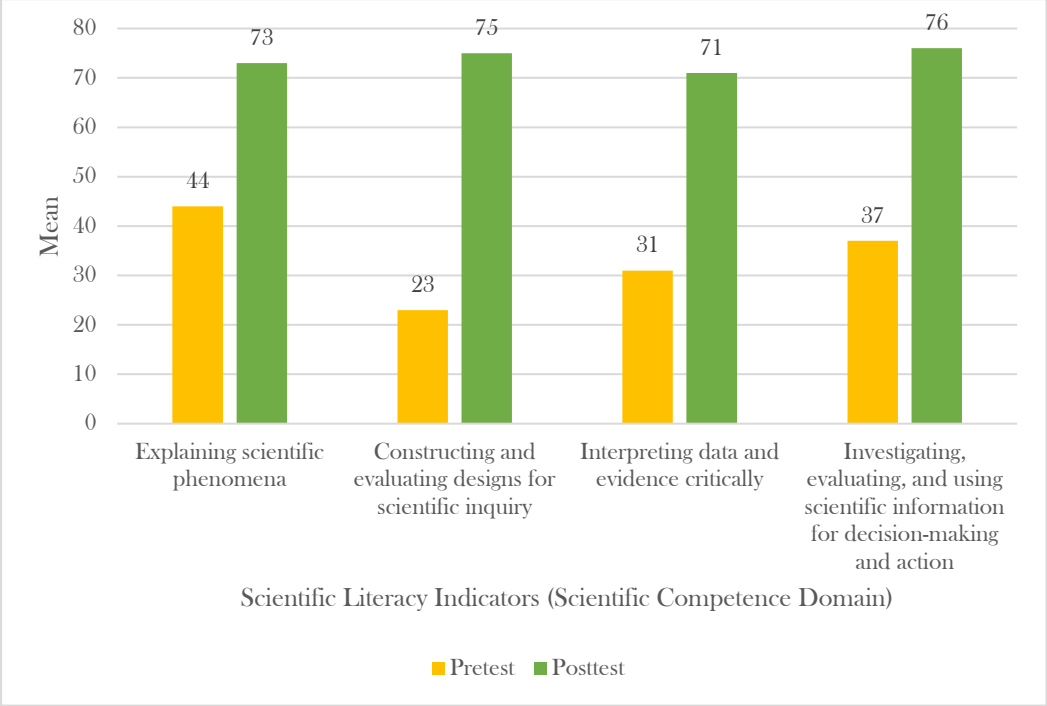


Figure 2. Percentage of Achievement for Scientific Literacy Indicators (Scientific Competence Domain)

The figure shows that all scientific-competence indicators increased substantially from pretest to posttest, with posttest means consistently above 70% (71–76%). The largest gain occurred in constructing and evaluating designs for scientific inquiry (23%–75%), confirming that guided inquiry effectively supports procedural and investigative competencies that are often weak at baseline among junior high school students (Amelia et al., 2023). However, the indicator interpreting data and evidence critically reached the lowest posttest achievement (71%), highlighting a persistent difficulty in students' evidence-based reasoning. This weakness may be attributed to students' challenges in connecting data to scientific claims, interpreting patterns in infographic representations, and drawing justified conclusions from complex global warming data. Such difficulties are consistent with broader findings that students often struggle with higher-order reasoning tasks, particularly those requiring interpretation and evaluation of evidence (Wardani et al., 2025). This result also reflects patterns observed in PISA, where many

Indonesian students remain at or below Level 2 proficiency, indicating limited ability to use scientific evidence for reasoning and decision-making. Although infographic-based multimedia supports visualization, it may not fully scaffold the cognitive processes required for deep evidence interpretation, especially for students with lower prior knowledge. Meanwhile, the relatively high achievement in using scientific information for decision-making (76%) suggests that the SETS orientation successfully enhanced contextual understanding by linking science concepts to environmental, technological, and societal issues (Fuddah & Nuha, 2026). Overall, these findings indicate that while the integration of SETS, guided inquiry, and infographic multimedia effectively improves multiple dimensions of scientific literacy, additional scaffolding and repeated practice are needed to strengthen evidence-based reasoning. Importantly, this study addresses the research gap identified in the literature by demonstrating that the integration of inquiry (process), SETS (context), and multimedia (cognitive support) provides a more comprehensive solution for developing scientific literacy in global warming education an approach that has been largely absent in prior studies that examined these components separately (Permatasari, 2022).

Based on the discussion above, the results of this study indicate that the SETS-oriented Guided Inquiry Learning model supported by infographic-based multimedia significantly improves students' scientific literacy, particularly in enhancing their scientific thinking skills. This model not only strengthens students' conceptual understanding of science but also develops their abilities in critical thinking, data processing, and evidence-based decision-making. These findings are consistent with previous research demonstrating that inquiry-based learning accelerates the development of scientific thinking competencies, enhances analytical skills, and improves students' problem-solving abilities in broader scientific contexts (Artini et al., 2018).

CONCLUSION

Based on the research conducted on the implementation of SETS-oriented Guided Inquiry Learning supported by infographic-based multimedia in Grade VII students at SMP Negeri 52 Surabaya, there was a significant improvement in students' scientific literacy on the topic of global warming. The results showed an increase in students' ability to explain scientific phenomena, design inquiry, and make evidence-based decisions in a more structured manner after the intervention. Statistical analysis using a paired-samples t-test indicated a significant difference between pretest and posttest scores ($p < 0.05$), while the average N-gain was categorized as medium. These findings indicate that Guided Inquiry Learning effectively promotes students' active engagement in inquiry processes, data analysis, and scientific reasoning. The integration of the SETS approach helps students connect scientific concepts with environmental issues, technology, and societal contexts, thereby enhancing the relevance and meaningfulness of learning. In addition, infographic-based multimedia supports students in understanding complex concepts and visualizing data, although the ability to interpret data and evidence remains relatively lower and requires further instructional emphasis. However, this study is limited by the use of a pre-experimental design without a control group, the relatively small sample size, and the short duration of the intervention, which may affect the generalizability of the findings. Therefore, future research is recommended to employ quasi-experimental designs with larger samples and longer implementation periods, as well as to explore strategies for strengthening students' evidence-based reasoning. Thus, the integration of SETS-oriented inquiry learning and infographic multimedia can serve as an effective instructional strategy to improve the quality of science learning and enhance students' scientific literacy.

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