BIO EDUCATIO
(*The Journal of Science and Biology Education*)
http: https://jurnal.unma.ac.id/index.php/BE
p-ISSN : 2541-2280
e-ISSN : 2541-4097
DOI: http://doi.org/10.31949/be.v10i2.15497

Bridging the Cognitive–Affective Gap: An Analysis of Elementary Students' Science Literacy and Scientific Attitudes

Arie Dwiyanti[1], Herli Salim[2], Deri Hendrawan[3]
[1] Faculty of Educational Sciences, Universitas Pendidikan Indonesia, Indonesia
[2] Faculty of Educational Sciences, Universitas Pendidikan Indonesia, Indonesia
[3] Faculty of Educational Sciences, Universitas Pendidikan Indonesia, Indonesia
Corresponding Author: ariedwiyanti@upi.edu

Article Info
Article History
Received: 12-08-2025
Revised: 27-09-2025
Accepted: 08-10-2025

Keywords:

Science literacy;
Scientific attitudes;
Cognitive–affective gap;
Elementary education;
Science learning

ABSTRACT
This study investigates the relationship between science literacy and scientific attitudes among elementary school students, with a particular focus on identifying imbalances between the cognitive and affective domains in science learning. Employing a quantitative descriptive design, data were collected from 35 fourth-grade students using validated, reliable instruments to measure science literacy and scientific attitudes. Descriptive statistical analysis revealed that students' science literacy remains low, while their scientific attitudes are relatively high. Pearson correlation analysis indicated a strong and significant positive relationship between the two variables ($r = 0.841$, $p < 0.001$). Despite this strong association, the findings highlight a critical gap, where positive scientific attitudes are not effectively translated into cognitive achievement. This suggests that current instructional practices may foster engagement but lack sufficient support for conceptual understanding and inquiry-based reasoning. The study contributes to the growing discourse on holistic science education by emphasizing the need for integrated instructional approaches that align affective engagement with cognitive development. These findings have important implications for designing more effective, evidence-based science learning strategies at the elementary level.

INTRODUCTION

Science learning at the elementary level is widely acknowledged as a critical foundation for developing students' scientific reasoning and evidence-based thinking. However, persistent empirical evidence indicates that students' science literacy remains below expected standards, reflecting a systemic gap between intended curriculum outcomes and actual classroom practices. This gap is not solely cognitive but also reflects insufficient development of scientific attitudes, which are essential for inquiry, skepticism, and critical reasoning. Prior studies suggest that instructional and affective factors interact in shaping literacy outcomes, yet these interactions are often underexplored in science education contexts (Chen et al., 2021). In practice, classroom instruction frequently emphasizes content coverage rather than meaningful engagement, limiting opportunities for students to develop both conceptual understanding and scientific dispositions. This imbalance suggests that current pedagogical approaches may inadequately address the

complexity of science learning, necessitating a more integrative framework that considers both cognitive and affective dimensions.

Recent research has highlighted the effectiveness of inquiry-based, problem-based, and project-based learning in enhancing science literacy and engagement (Kang, 2022; Machado & Nahar, 2023; Sugiharti & Osma, 2024; Suryanata et al., 2025). These approaches are often associated with improvements in higher-order thinking and conceptual understanding. Concurrently, a growing body of literature emphasizes the role of scientific attitudes—such as curiosity, openness to evidence, and persistence—in influencing learning outcomes (Rossi et al., 2021; Wibawa et al., 2023; Junnanto & Masithoh, 2025). Systematic reviews further indicate that fostering scientific attitudes requires intentional instructional strategies rather than incidental exposure (Saputri et al., 2025). However, a critical examination reveals that many studies tend to report positive effects of instructional models without sufficiently analyzing the contextual and affective mechanisms underlying these outcomes. As a result, the field risks oversimplifying complex learning processes and overlooking the interdependence between cognitive achievement and affective engagement.

Despite the increasing attention to both science literacy and scientific attitudes, existing research largely treats these constructs as separate domains. Empirical studies have examined their relationships with learning outcomes (Aritonang et al., 2021; Kusuma et al., 2021; Ocak et al., 2021), while others have explored students' perceptions and dispositions toward scientific texts and learning (Gürler, 2022). However, such approaches often fail to capture the dynamic interaction between knowing and valuing in science learning. Furthermore, many studies prioritize intervention-based designs without first establishing a comprehensive baseline profile of students' abilities and attitudes. This limitation constrains the development of targeted instructional strategies grounded in actual learner needs. The lack of integrated profiling is particularly evident at the elementary level, where foundational scientific competence is still developing. Therefore, a more holistic analytical approach is required to bridge this gap and provide a deeper understanding of how cognitive and affective dimensions jointly shape science learning.

Positioned within the global discourse on holistic and multidimensional learning, this study advances an integrative perspective that connects science literacy and scientific attitudes within a unified framework. Contemporary educational research increasingly critiques reductionist approaches that prioritize measurable cognitive outcomes while marginalizing affective dimensions (Brewe et al., 2023; Limbu, 2024). Emerging evidence from STEM education further demonstrates that meaningful learning occurs when cognitive and affective domains are simultaneously activated (Yllana-Prieto et al., 2023; Yun & Cho, 2022). In this context, the present study contributes by operationalizing this integration through a structured analysis of students' literacy and attitudes. Additionally, the study aligns with current developments in science assessment that emphasize multidimensional measurement and contextual relevance (Muniroh et al., 2022; Wahyuni et al., 2024). By situating itself within these global debates, this research offers both conceptual refinement and empirical evidence to support a more holistic approach to science education.

The objective of this study is to analyze the profile of science literacy and scientific attitudes among elementary school students within an integrated analytical framework. Specifically, the study aims to examine students' achievement across key dimensions of science literacy, including

knowledge, processes, and contextual application, alongside core indicators of scientific attitudes. In addition, the study seeks to investigate the relationship between these constructs to better understand their combined influence on learning outcomes. Unlike prior studies that predominantly focus on intervention effects, this research adopts a diagnostic approach that provides a comprehensive baseline of students' cognitive and affective development. The findings are expected to generate evidence-based insights to inform the design of more balanced instructional strategies that address both domains simultaneously. Ultimately, this study contributes to the advancement of science education by promoting learning practices that are not only cognitively effective but also capable of fostering enduring scientific dispositions.

METHOD

Research Design

This study employed a quantitative descriptive approach within an exploratory research design. The selection of this design was grounded in the objective of systematically profiling students' science literacy and scientific attitudes without manipulating variables. An exploratory-descriptive framework is particularly well-suited to identifying patterns, distributions, and relationships in naturally occurring educational settings, especially when baseline data are required for subsequent intervention studies. In this context, the study aimed to generate an empirical foundation for understanding students' cognitive and affective characteristics in science learning. The design enables comprehensive mapping of students' competencies across multiple dimensions while maintaining ecological validity. Furthermore, the quantitative orientation ensures objectivity in measurement and enables statistical interpretation of findings. This approach aligns with the study's objective of producing data-driven insights to inform the development of more targeted, evidence-based instructional strategies in elementary science education.

Data Sources / Participants

The study was conducted at an elementary school located in Serang City, Banten Province, Indonesia. The population consisted of all fourth-grade students, and 35 students were selected as the research sample. The sampling technique employed was total sampling, given the relatively small population size and the study's objective of obtaining a comprehensive profile of all students in the class. The participants represent a typical elementary classroom context, making the findings relevant for similar educational settings. The selection of participants was based on their active involvement in science learning activities, ensuring that the data reflected authentic learning experiences. This sample size is considered adequate for descriptive quantitative analysis, particularly in exploratory studies aimed at profiling variables rather than generalizing across broader populations. The characteristics of the participants, including their grade level and learning context, were aligned with the study's focus on early-stage development of science literacy and scientific attitudes.

Instruments / Data Collection

Data were collected using two structured instruments designed to measure science literacy and scientific attitudes. The science literacy instrument consisted of three dimensions: scientific knowledge, scientific processes, and scientific context, comprising a total of 25 items during the trial phase. The scientific attitude instrument included five dimensions: curiosity, open-mindedness, healthy skepticism, persistence, and collaboration, also consisting of 25 items. The

development of the instruments was based on established theoretical frameworks, including science literacy assessment models and scientific attitude indicators.

Table 1. Instrument Blueprint (Trial Stage)

Variable	Dimension	Indicator	Number of Items	Max Score per Item
Science Literacy	Knowledge	Understanding of scientific concepts (plant topic)	8	1
	Process	Ability to apply scientific methods	8	1
	Context	Application of science in daily life	9	1
Total			**25**	**25**
Scientific Attitude	Curiosity	Interest in exploring scientific questions	5	4
	Open-mindedness	Acceptance of evidence-based reasoning	5	4
	Healthy skepticism	Critical evaluation of claims	5	4
	Persistence	Consistency in problem-solving	5	4
	Collaboration	Ability to work with others	5	4
Total			**25**	**100**

The instrument validation results indicate that the majority of items met the required validity criteria based on the Pearson Product-Moment correlation. For the science literacy instrument, 21 of 25 items were initially valid, while 4 were excluded due to low correlations. After further refinement, 20 items were retained for the final instrument. Similarly, for the scientific attitude instrument, 19 of 25 items were valid; 6 were removed during validation, resulting in 20 valid items for subsequent data collection. In terms of reliability, the instruments demonstrated satisfactory internal consistency. The science literacy instrument showed a Cronbach's Alpha coefficient of 0.723 at the trial stage, which improved to 0.806 after revision, indicating good reliability. Likewise, the scientific attitude instrument achieved a Cronbach's Alpha of 0.753 during the trial phase and 0.824 in the final version, indicating good reliability. These results confirm that both instruments possess adequate psychometric properties, ensuring that they are valid and reliable for measuring students' science literacy and scientific attitudes. The refinement process improved measurement quality, thereby strengthening the accuracy and consistency of the data collected in this study.

Procedure

The research procedure was conducted systematically and sequentially to ensure methodological rigor. The process began with a literature review to establish the theoretical foundation and define key constructs. This was followed by field observation to understand the contextual characteristics of the study setting. Based on these stages, the researchers developed the research instruments aligned with the study objectives. Subsequently, an instrument trial was

conducted to evaluate validity and reliability, followed by item analysis to determine the final set of valid and reliable items. After refinement, the finalized instruments were administered to the participants during the data collection phase. The collected data were then processed and analyzed using appropriate statistical techniques. Finally, the study concluded with the interpretation of results and the formulation of conclusions. This structured procedure ensures that the study can be replicated in similar contexts with comparable methodological steps.

Data Analysis

Data were analyzed using **descriptive statistical techniques** to categorize students' levels of science literacy and scientific attitudes. The scoring process involved converting raw scores into percentages using the following formula:

$$P = \frac{S}{S_{max}} \times 100\%$$

where *P* represents the percentage score, *S* is the obtained score, and *Smax* is the maximum possible score. The results were then classified into qualitative categories based on predetermined criteria.

Table 2. Category Criteria for Science Literacy and Scientific Attitudes

Category	Percentage (%)	Science Literacy Score	Scientific Attitude Score
Very High	90–100	23–25	90–100
High	70–89	18–22	70–89
Moderate	50–69	13–17	50–69
Low	30–49	8–12	30–49
Very Low	<30	<7	<30

The analyzed data were presented as **frequency distributions and bar charts** to provide a comprehensive overview of students' performance patterns. This approach allows for clear interpretation and facilitates the identification of dominant trends in both variables.

Ethical Considerations

Ethical standards were strictly maintained throughout the research process. Prior to data collection, permission was obtained from the school authorities, and participants were informed about the purpose of the study. Informed consent was obtained to ensure voluntary participation. The confidentiality of participants' data was maintained by anonymizing all personal information and reporting results in aggregate. The study adhered to principles of academic integrity, including proper data handling and avoidance of fabrication or manipulation. All procedures were conducted in accordance with ethical guidelines for educational research, ensuring that participants' rights and well-being were fully protected.

RESULTS

The data in this study consist of two main variables, namely students' science literacy and scientific attitudes, collected from 35 fourth-grade students. The analysis was conducted to identify

the distribution patterns, central tendencies, and relationships between these variables, providing a comprehensive profile of students' cognitive and affective development in science learning .

Profile of Students' Science Literacy

Table 3. Distribution of Students' Science Literacy Levels

Category	Frequency	Percentage (%)
Very High	0	0.0
High	6	17.1
Moderate	9	25.7
Low	10	28.6
Very Low	10	28.6
Total	35	
Mean Score	11.29	
Category	Low	

Based on Table 3, the distribution of students' science literacy shows a skew toward lower performance levels. Notably, no students achieved the "Very High" category, while the majority were concentrated in the "Low" and "Very Low" categories, each accounting for 28.6% of the sample. Only a limited proportion of students reached the "High" (17.1%) and "Moderate" (25.7%) levels. The mean score of 11.29, categorized as "Low," further confirms that overall science literacy remains underdeveloped. Rather than merely indicating low achievement, this pattern suggests a systemic limitation in students' ability to integrate conceptual understanding, scientific processes, and contextual application. The absence of high-performing students indicates a ceiling effect in learning outcomes, suggesting that instructional practices may not sufficiently support advanced cognitive development. Furthermore, the relatively balanced distribution between "Low" and "Very Low" categories indicates that the issue is not isolated but widespread across the cohort.

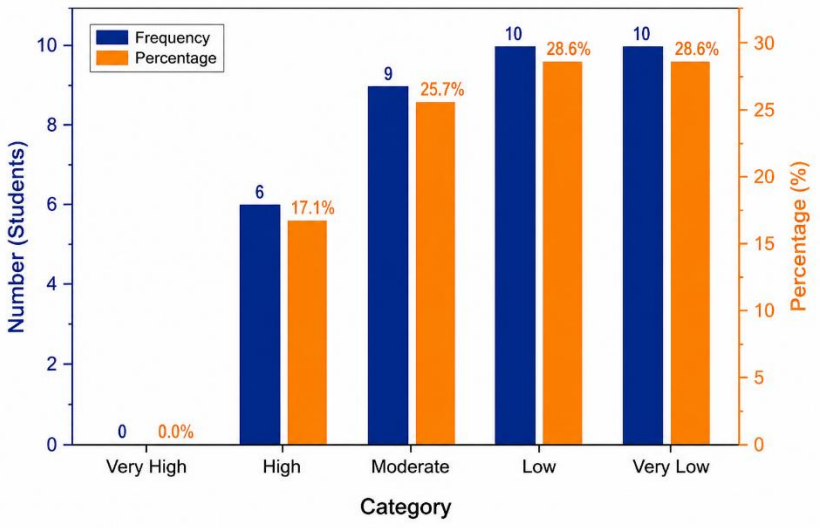

Figure 1(a). Science Literacy Profile

The visual representation in Figure 1(a) reinforces this trend, clearly illustrating the dominance of lower categories. The near-equal proportions of "Low" and "Very Low" groups highlight a **critical learning gap**, suggesting that most students have not yet achieved functional science literacy. This finding implies that current instructional approaches may insufficiently promote inquiry, reasoning, and real-world application, thereby limiting students' ability to construct meaningful scientific understanding.

Profile of Students' Scientific Attitudes

Table 4. Distribution of Students' Scientific Attitudes

Category	Frequency	Percentage (%)
Very High	3	8.6
High	19	54.3
Moderate	11	31.4
Low	2	5.7
Very Low	0	0.0
Total	35	
Mean Score	73.74	
Category	High	

In contrast to science literacy, Table 4 shows that students' scientific attitudes are generally well developed. A majority of students (54.3%) fall within the "High" category, followed by 31.4% in the "Moderate" category. A smaller proportion (8.6%) achieved the "Very High" level, while only 5.7% were categorized as "Low," and none were in the "Very Low" category. The mean score of 73.74 confirms that, on average, students demonstrate positive scientific dispositions. This distribution indicates that students have developed **affective readiness toward science**, including curiosity, openness to evidence, and collaborative tendencies. However, the relatively small proportion of students in the "Very High" category suggests that these attitudes, while present, may not yet be fully internalized or consistently applied in learning contexts.

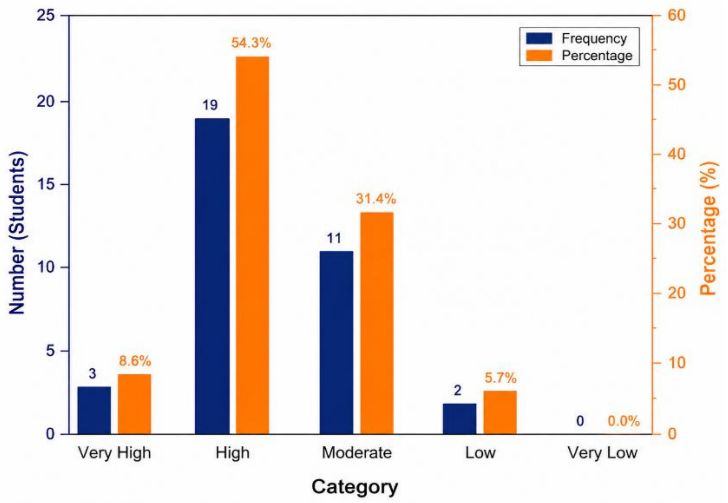

Figure 1(b). Scientific Attitude Profile

Figure 1(b) highlights the concentration of students in the "High" category, contrasting sharply with the distribution observed for science literacy. This divergence suggests that while students are effectively prepared to engage in scientific learning, this readiness is not yet translated into strong cognitive performance. Such a pattern indicates a disconnect between students' dispositions and their actual mastery of scientific concepts and processes.

Comparative Pattern between Cognitive and Affective Domains

A cross-variable comparison reveals a significant disparity between science literacy (cognitive domain) and scientific attitudes (affective domain). While students demonstrate relatively strong attitudes toward science, their ability to apply scientific knowledge and reasoning remains limited. This imbalance suggests that current learning environments may support engagement and interest but fail to effectively facilitate deeper conceptual understanding. From an analytical perspective, this finding highlights a latent inefficiency in instructional alignment, where affective engagement is not adequately leveraged to enhance cognitive outcomes. The coexistence of high attitudes and low literacy indicates that positive dispositions alone are insufficient without structured opportunities for inquiry-based and application-oriented learning.

Correlation between Science Literacy and Scientific Attitudes

Table 5. Correlation Analysis Results

Analysis Method	Indicator	Value	Interpretation
Pearson Correlation	Correlation Coefficient	0.841	Strong
	Sig. (2-tailed)	0.000	Significant

The Pearson correlation analysis reveals a **strong positive relationship** between science literacy and scientific attitudes ($r = 0.841$, $p < 0.001$). This indicates that higher levels of science literacy are consistently associated with stronger scientific attitudes among students. The magnitude of the correlation suggests a substantial effect size, highlighting a meaningful interdependence between cognitive and affective domains. Furthermore, the statistical significance ($p < 0.001$) confirms that the observed relationship is unlikely to have occurred by chance, thereby providing robust empirical support for the proposed association. This implies that improvements in one domain are likely to influence the other, reinforcing the importance of integrated instructional approaches. The strong correlation also validates the theoretical assumption that scientific attitudes play a critical role in shaping students' learning processes and outcomes.

Summary of Key Findings

Overall, the findings reveal three critical patterns. First, students' science literacy remains low, with a concentration in lower performance categories. Second, students' scientific attitudes are relatively strong, indicating positive engagement and readiness for learning. Third, despite this disparity, a strong positive correlation exists between the two variables, suggesting that they are closely interconnected. These results indicate that the primary challenge in science learning is not the absence of student engagement but the ineffective translation of affective readiness into cognitive achievement. Therefore, the findings provide a strong empirical basis for developing instructional strategies that more effectively integrate both domains.

DISCUSSION

The findings of this study reveal a critical imbalance between students' cognitive and affective development in science learning, where scientific attitudes are relatively strong while science literacy remains low. This pattern reflects a phenomenon widely discussed in the literature as the "high motivation–low achievement paradox", in which students demonstrate positive dispositions toward learning but fail to achieve corresponding academic outcomes (Karakolidis et al., 2019). Previous research confirms that motivational and affective factors significantly influence learning processes; however, their impact on achievement is mediated by the quality of cognitive engagement and instructional design (Zhang & Bae, 2020). In this context, the present findings suggest that students' willingness to engage in scientific thinking is not adequately supported by opportunities to develop conceptual understanding and inquiry skills. This aligns with recent systematic reviews emphasizing that early science literacy development requires not only engagement but also structured cognitive scaffolding to ensure meaningful learning (Roy et al., 2025).

The results also resonate with studies highlighting the potential of inquiry-based and student-centered learning approaches to enhance both engagement and learning outcomes, yet with important limitations. While such approaches have been shown to foster scientific attitudes and participation (Suprianti et al., 2021; Sarwi et al., 2020), their effectiveness in improving science literacy depends heavily on implementation quality, scaffolding, and contextual alignment. Empirical evidence indicates that poorly structured inquiry or student-centered learning may lead to superficial engagement without deep conceptual understanding (Soubra et al., 2022; Vieira et al., 2021). The present study extends this critique by demonstrating that positive scientific attitudes do not automatically translate into improved literacy performance. This finding challenges overly optimistic assumptions in the literature that equate active learning with cognitive gains, emphasizing instead the need for instructional precision and pedagogical depth.

A central contribution of this study lies in identifying a discrepancy between the strength of the relationship and the disparity in actual performance levels. Although a strong positive correlation was found between science literacy and scientific attitudes ($r = 0.841$, $p < 0.001$), the observed imbalance indicates that this relationship is not fully actualized in practice. This finding is consistent with meta-analytic evidence showing that attitudes toward science are significant predictors of achievement, yet their influence is contingent upon mediating variables such as instructional quality and epistemic beliefs (Mao et al., 2021; Karakolidis et al., 2019). Additional studies have also demonstrated that affective and cognitive domains are closely linked but may develop at different rates depending on learning conditions (Hernández-Barco et al., 2024; Yıldırım, 2020). Therefore, the present results suggest that the strong statistical relationship reflects potential rather than realized learning outcomes, pointing to a gap between theoretical interdependence and classroom practice.

From a theoretical perspective, these findings reinforce the importance of adopting a holistic and multidimensional framework in science education. Contemporary research increasingly critiques reductionist approaches that separate cognitive and affective domains, advocating instead for integrated models that emphasize their dynamic interaction (Miseliunaite et al., 2022; Çilekrenkli & Kaya, 2023). The strong correlation observed in this study supports this perspective, confirming that science learning is inherently interconnected across domains. However, the

imbalance identified suggests that current instructional practices fail to optimize this interaction. This study therefore contributes to the global discourse by providing empirical evidence that supports holistic learning theories while simultaneously highlighting the challenges of their practical implementation in elementary education contexts.

Pedagogically, the findings underscore the necessity of instructional alignment that bridges affective engagement and cognitive development. While students demonstrate readiness through positive scientific attitudes, this potential remains underutilized without structured learning experiences that promote conceptual understanding and inquiry skills. Research shows that guided inquiry, scaffolding strategies, and contextualized learning approaches can effectively integrate these domains when implemented with sufficient support (Yanti et al., 2023; Suprianti et al., 2021). Additionally, STEM-based and technology-enhanced learning environments have been found to enhance both motivation and achievement when designed to connect affective engagement with cognitive tasks (AlAli & Yousef, 2024; Yıldırım, 2020). Therefore, improving science literacy requires a shift from surface-level engagement toward deep, structured, and evidence-based instructional design that transforms curiosity into scientific reasoning.

Finally, this study provides important implications for future research by highlighting the need to examine the mechanisms through which affective factors translate into cognitive gains. While previous studies have established the relationship between scientific attitudes and learning outcomes (Mustain et al., 2021; Al Masquri, 2024), the present findings indicate that this relationship is not automatically realized in classroom practice. Future research should therefore focus on identifying mediating variables such as instructional quality, epistemic beliefs, and learning environment design. Longitudinal and experimental studies are particularly needed to investigate how integrated instructional models can effectively bridge this gap. Furthermore, expanding research across diverse contexts will contribute to a more comprehensive understanding of how cognitive–affective interactions operate in science education globally. In this regard, the present study not only confirms existing theoretical assumptions but also advances the field by revealing a critical gap between potential and practice.

CONCLUSION

This study identifies a fundamental imbalance in elementary science learning, in which students exhibit relatively strong scientific attitudes but limited scientific literacy. Although a strong positive association exists between these domains, the findings indicate that this relationship is not fully translated into actual learning outcomes. This suggests that affective readiness alone is insufficient without instructional structures that actively support conceptual understanding and scientific reasoning. Consequently, the study advances the perspective that effective science learning requires deliberate alignment between engagement and cognitive development rather than treating them as independently evolving constructs. However, several limitations should be acknowledged. The use of a descriptive design restricts causal interpretation, and the focus on a single school context may limit broader generalizability. In addition, the study does not explicitly examine mediating variables—such as instructional quality, scaffolding strategies, or epistemic beliefs—that may influence the transformation of scientific attitudes into literacy outcomes. These constraints indicate that the observed relationship reflects potential rather than fully realized learning processes. Building on these findings, the study offers both theoretical and practical

implications. Theoretically, it supports a holistic framework emphasizing the dynamic interplay between cognitive and affective domains in science education. Practically speaking, it highlights the need for instructional designs that intentionally connect students' curiosity to structured inquiry and knowledge construction. Future research should extend this work through experimental and longitudinal approaches, focusing on integrative learning models and exploring mediating mechanisms across diverse educational settings to better understand how affective engagement can be effectively converted into cognitive achievement.

ADDITIONAL INFORMATION

Section	Description
Funding	This research received no external funding.
Conflict of Interest	The authors declare no conflict of interest.
Author Contributions	All authors contributed to this study. Author 1 led conceptualization, methodology, and drafting; Author 2 conducted data collection and analysis; Author 3 reviewed and edited the manuscript. All authors approved the final version.
Data Availability	Data are available from the corresponding author upon reasonable request.
Ethical Approval	The study adhered to ethical standards. Informed consent was obtained, and data confidentiality was ensured.
AI Usage Statement	AI tools were used only for language refinement. All scientific content and analysis were conducted by the authors.

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