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Synergy of Science Literacy and Student Sustainability Literacy in Biology Learning Towards the Sustainable Development Goals Agenda

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Abstract

The urgency of this research is to strengthen the synergy between science literacy and students' sustainability literacy in biology learning to support the achievement of the Sustainable Development Goals (SDGs) .The Sustainable Development Goals (SDGs) agenda requires biology learning to be oriented not only towards mastering concepts but also towards fostering ecological awareness, sustainability mindsets, and student action competencies to address the 21st-century environmental crisis. The low achievement in science literacy among Indonesian students in the Programme for International Student Assessment, coupled with biology learning that is predominantly theoretical and memorized, underscores the importance of strengthening the synergy between science literacy and sustainability literacy. The research aims to analyze the correlation between science literacy and sustainability literacy among grade X students in ecosystem materials, as a basis for developing biology learning that supports the SDGs agenda. The research sample comprised 276 students selected through purposive sampling from SN4, SN10, SN14, and SN16. The research instrument consisted of 20 multiple-choice science literacy tests, 18 statements of science identity questionnaires, and 18 statements of literacy questionnaires. Data were analyzed using SPSS for normality, homogeneity, linearity, moment product correlation, simple linear regression, and the coefficient of determination. The results of the study show variation in achievement across schools. SN10 obtained the highest average scores in science literacy (85.46%) and sustainability literacy (92.36%). Meanwhile, SN16 had the lowest average sustainability literacy score at 56%. Knowledge displacement in sustainability literacy reached the highest level across schools, while the dimensions of skills and mindset were lower. The correlation results showed a positive and significant relationship between science literacy and sustainability literacy, with a very strong correlation in SN14 of r= 0.909 with R2=82.7%, and SN10 of r= 0.894 with R2=79.9%. These findings confirm that science literacy is an important foundation for building students' sustainability literacy, so biology learning on ecosystem materials needs to be integrated to support the achievement of the Sustainable Development Goals agenda.

Keywords: *Science Literacy, Sustainability Literacy, Ecosystem, Sustainable Development Goals*

Introduction

Entering the 21st century, the rapid development of science and technology requires students to think critically and creatively and to make decisions based on data and scientific facts. One of the main skills students need to face these challenges is scientific literacy. Science literacy includes not only an understanding of scientific concepts and principles but also the

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ability to apply them in everyday life (Ke et al., 2021; Busch & Rajwade, 2024). Individuals with adequate science literacy skills will be able to identify scientific questions, draw conclusions based on strong evidence, and understand the ethical implications of scientific advances. Without good science literacy, people will have difficulty understanding essential information about health, technology, and the environment, hindering progress and well-being (Putri et al., 2023).

However, theoretical and empirical challenges in the modern era show that scientific literacy alone is no longer sufficient. Given global crises such as climate change, ecosystem damage, and growing environmental problems, the world of education is required to produce a generation that is also competent to act sustainably. This is where sustainability literacy comes in; it becomes a crucial pillar (Sani, 2025). Sustainability literacy involves a deep understanding of how current human actions affect ecosystems, natural resources, and future socio-economic well-being (Putri et al., 2025). The main problem underlying this research is the lack of optimal integration and synergy between students' scientific understanding and their sustainability awareness in school learning (Hasyim et al., 2025).

As a result, the scientific knowledge gained by students is often isolated and has not been fully translated into tangible action competencies to support the sustainable development agenda or the *Sustainable Development Goals* (SDGs). A number of previous studies have consistently shown that students' science literacy in Indonesia remains relatively low compared with other countries (Yusmar & Fadilah, 2023; Haka et al., 2025). Based on historical data from the *Programme for International Student Assessment* (PISA) released by the OECD, Indonesian students' science literacy scores remain below the international average (Fuadi et al., 2020; Putri et al., 2025). This indicates that students still have difficulty in relating scientific information to real-life phenomena. Some of the factors identified by previous studies as main obstacles include teachers' conventional teaching approach, limited laboratory facilities, and a lack of emphasis on literacy in the learning evaluation process (Nazifah & Asrizal, 2022).

On the other hand, the study on sustainability literacy notes that although various global initiatives and environmental awareness guidelines have been developed, their implementation in formal education still faces major obstacles (Putri et al., 2023). Many students know the basic concepts of sustainable development as a theory for exam purposes, but do not yet have the mindset and decision-making skills to address real issues around them, such as waste management and deforestation (Putri et al., 2023). The limitation of these new studies is that they still tend to see science literacy and sustainability literacy as two separate things, so that the practical solutions offered by previous research have not been able to touch the root of integrative learning problems (Yanti & Erni, 2024).

Theoretically, science literacy and sustainability literacy are two complementary competencies that should interact synergistically (Kuehl et al., 2023). Science literacy provides an analytical knife in the form of a rational scientific approach, while sustainability literacy provides a direction for how science must contribute to maintaining a balance among environmental, social, and economic aspects. However, there is a gap (*Gap*) between the idealism of the national curriculum and the reality of its implementation in the field. So far, it is still very rare to find research that specifically examines how the synergy between the two literacies manifests in real life among students learning Biology, the subject that is closest to the issues of ecosystems and the sustainability of living things.

In addition, the empirical portrait of this integrative capability remains largely at the national macro level, thereby overlooking the distinctive characteristics and local environmental challenges faced by developing urban areas in the region, particularly at the high school level in Bandar Lampung City. Based on the gap analysis, this study poses the question: *What is the synergy profile between science literacy and sustainability literacy among students in Biology learning at SMA Bandar Lampung City, in order to equip them for the Sustainable Development Goals (SDGs) agenda?* In line with this, this study aims to provide a comprehensive, measurable, and in-depth picture of the actual state of integrating these two competencies among the younger generation at the high school level in Bandar Lampung. The novelty of this study lies in its focus on the synergy and relationship between science literacy and sustainability literacy, examined simultaneously within the scope of Biology subjects at the secondary school level. The findings of this study not only fill the theoretical gap in science education literacy in Indonesia but also provide a concrete, context-based practical contribution for education policymakers, principals, and teachers in Bandar Lampung to design innovative learning strategies and relevant teaching materials to support the achievement of SDGs targets.

Method

This study uses a quantitative approach and a correlational method to determine whether there is a relationship between the independent variable (Science Literacy) and the dependent variable (Sustainability Literacy). The research was conducted at four State High Schools (SMAN) in Bandar Lampung City, SMAN 4, SMAN 10, SMAN 14, and SMAN 16, during the even semester of the 2025/2026 school year. The selection of school locations was carried out using *purposive sampling techniques*, based on variations in schools' accreditation status and the availability of relevant supporting data for research purposes. The subjects or samples in this study are class X students from each of these schools, with the following numbers: 68 students in SN 4, 72 students in SN 10, 68 students in SN 14, and 68 students in SN 16.

Data collection instruments are of two main types. First, a science literacy test consisting of 20 multiple-choice questions was developed based on *the indicators of the Program for International Student Assessment* on Ecosystem materials in Biology learning. Second, a sustainability literacy questionnaire consisting of 18 statements using the Likert scale model.

Table 1. *Science Literacy Test Instrument Grid*

No	Learning Objectives	Science Competency	Level	Question Indicator
1	TP 1: Identify biotic & abiotic components in different types of ecosystems	Explaining scientific phenomena	Level 1a	Identify biotic and abiotic components in ecosystem types.
		Explaining scientific phenomena	Level 2	Explain the biotic-abiotic relationship with examples of the global environment.
		Evaluate & design research	Level 3	Evaluate scientific research methods in ecosystem studies.
		Interpreting data & scientific evidence	Level 4	Interpret graphs/tables of population changes due to environmental changes.
2	TP 2: Analyze the interaction of ecosystem components & sustainability relevance	Explaining scientific phenomena	Level 1b	Explain the relationship between human activity and real climate change.
		Explaining scientific phenomena	Level 2	Identify the impact of climate change on global ecosystems.
		Evaluate & design research	Level 3	Evaluate the impact of human activities based on data/information.
		Interpreting data & scientific evidence	Level 4	Analyze data/graphs of population change due to climate change.
3	TP 3: Evaluating the reciprocal relationship of living things in the	Explaining scientific phenomena	Level 2	Identify the mutual relationship of living beings and the environment globally.
		Evaluate & design research	Level 3	Evaluate the impact of human activities on the balance of ecosystems.

No	Learning Objectives	Science Competency	Level	Question Indicator
	principle of sustainability	Evaluate & design research	Level 5	Evaluate the impact of human activities based on advanced data/information.
4	TP 4: Designing solutions to environmental problems with sustainability principles	Explaining scientific phenomena	Level 1a	Identify environmental problems due to climate change.
		Evaluate & design research	Level 3	Evaluate research methods on the impact of climate change.
		Interpreting data & scientific evidence	Level 3	Interpret carbon emission data and their impact on ecosystems.
5	TP 5: Conceptualizing the biogeochemical cycle (mind mapping) & sustainability relevance	Explaining scientific phenomena	Level 2	Identify the key components of the biogeochemical cycle & its global role.
		Evaluate & design research	Level 3	Evaluate experimental methods/research models of biogeochemical cycles.
		Interpreting data & scientific evidence	Level 4	Interpreting global temperature rising trends, CO2 levels, or NO patterns.
6	TP 6: Reflect on attitudes and actions to protect the ecosystem for the future	Explaining scientific phenomena	Level 2	Identify the factors causing global environmental change & their impacts.
		Evaluate & design research	Level 3	Evaluate the weaknesses/advantages of climate impact research methods.
		Interpreting data & scientific evidence	Level 4	Interpret pollution or deforestation data and their impacts.

This assessment matrix serves as a comprehensive blueprint for measuring student progress across six core learning objectives (TP 1 to TP 6), bridging foundational biological knowledge with sustainability action. The table systematically categorizes these objectives into three primary science competencies: explaining scientific phenomena, evaluating and designing research, and interpreting scientific data. By utilizing a progression of cognitive levels ranging from Level 1 to Level 5, the framework ensures that students move beyond simple identification of biotic and abiotic components toward higher-order skills, such as analyzing population changes and evaluating research methodologies related to climate change.

Furthermore, the matrix emphasizes the real-world application of science through specific question indicators focused on global environmental challenges. It requires students to interpret complex data, such as carbon emission trends and deforestation patterns, while designing solutions grounded in sustainability principles. Ultimately, the structure of this table aims to cultivate a holistic form of literacy where cognitive mastery of biogeochemical cycles and ecosystem interactions leads to meaningful reflection on the actions needed to protect the environment for future generations.

Table 2. *Sustainability Literacy Questionnaire Grid*

Indicator	Aspects Assessed	Statement No.	Statement No.	Maximum Score
Knowledge	1. Understanding of the relationship between humans and ecosystems 2. Knowledge of social and economic systems (Global–Local) 3. Understanding the transition to sustainability	(Favored)	(Unfavourable)	Maximum Score
Knowledge	1. Understanding of the relationship between humans and ecosystems 2. Knowledge of social and economic systems (Global–Local) 3. Understanding the transition to sustainability	1,3,5	2,4,6	4
Skills	1. Social skills and collaboration 2. Personal skills and self-management 3. Critical and systematic thinking skills	7,9,11	8,10,12	4

Indicator	Aspects Assessed	Statement No.	Statement No.	Maximum Score
Mindset	1. Ability to understand the long-term impact of an action 2. Analyze sustainability issues 3. Assess awareness and willingness to design sustainable future solutions	13,14,15	16,17,18	4

This evaluation framework matrix categorizes the assessment of sustainability literacy into three distinct dimensions: Knowledge, Skills, and Mindset. Each dimension is evaluated using specific behavioral or conceptual aspects, which are measured through a balanced mix of positive ("Favored") and negative ("Unfavourable") statements across 18 items. The "Knowledge" dimension assesses the structural understanding of human-ecosystem relationships, socio-economic systems, and sustainability transitions (Statements 1–6). The "Skills" dimension measures actionable competencies, focusing on collaboration, self-management, and critical thinking (Statements 7–12).

Lastly, the "Mindset" dimension evaluates long-term impact awareness, issue analysis, and the willingness to design future solutions (Statements 13–18). Each item within these categories carries a standardized maximum score of 4, ensuring a balanced quantitative evaluation across all indicators. Before being applied in the field, both instruments have gone through the stages of expert *judgment* and field trials to measure the level of empirical validity using the biserial point correlation formula (rpbis):

$$\text{formula } r_{pbis} = \frac{M_p - M_t}{S_t}\sqrt{\frac{p}{q}}$$

With Description rpbis: Biseral point correlation coefficient, M_P: Means the score that answers the item correctly for the correlation, Mt: Mean total score, St: Standard deviation for all items, p :P Proposal Subject Who Answered Correctly q : 1-P.

The reliability test of the instrument was carried out using Cronbach's Alpha formula (r11):

$r_{11} = \left(\frac{K}{K-1}\right)\left(1 - \frac{M(k-M}{kSt2}\right)$ with the description Remarks: r_{11}: Reliability of the instrument, k: Number of question items, St^2: Total score variance, M: Average total score The test results showed that the value of the validity coefficient for 20 questions of the science literacy test and 18 items of the sustainability literacy questionnaire was at 0.834, which was categorized as having a very high level of validity and a reliability value above 0.70,so that all instruments are declared authentic and reliable to use.

Data analysis is carried out through several logical sequential stages. The first stage is the analysis prerequisite test, which includes a normality test using the *Kolmogorov-Smirnov* method and a homogeneity of variance test using *Levene's test*. The decision-making criterion for this prerequisite test is that if the significance value (Sig.) > 0.05, the data are considered normally distributed and drawn from a homogeneous population. Once the prerequisites were met, the analysis was followed by the *Pearson product-moment correlation test* to see the strength (r-coefficient) and the direction of the relationship between the variables. The correlation formula used is:

$r_{xy} = (n\Sigma XY - (\Sigma X)(\Sigma Y)) / \sqrt{[n\Sigma X^2 - (\Sigma X)^2][n\Sigma Y^2 - (\Sigma Y)^2]}$ The strength of the relationship is categorized based on the value of the correlation coefficient (r) obtained from the calculation.

The value of the correlation coefficient (r) was then interpreted based on standard intervals (0.00–0.199: Very Low; 0.20–0.399: Low; 0.40–0.599: Moderate; 0.60–0.799: Strong; 0.80–1.000: Very Strong). The final stage of the analysis is to perform a simple linear regression test using the equation model Y = a + X (where Y is Sustainability Literacy and X is Science Literacy) to see the magnitude of the mathematical influence as well as the contribution of the free variable to the bound variable through the value of the determination coefficient (R2/*R-Square*).

Result and Discussion

Synergy Analysis of Science Literacy Profile and Student Science Identity in Bandar Lampung City

Table 3. *Validity Results Test*

No.	Item Number		Validity Coefficient (r)	Criteria	Status
	Scientific Literacy Test	Sustainability Literacy Questionnaire			
1	Items 1 – 20	18 Statements	0.834	Very High	Valid

The research instruments implemented across the four sample schools (SMA Negeri 4, SMA Negeri 10, SMA Negeri 14, and SMA Negeri 16 Bandar Lampung) indicate a validity coefficient of 0.834 which falls under the Very High criteria (0.81 < r 1.00). Therefore, the instruments are deemed valid and highly feasible for data collection in the study.

Tabel 4. *Reliability Results Test*

No.	Item Number		Reliability Coefficient (r)	Criteria	Status
	Scientific Literacy Test	Sustainability Literacy Questionnaire			
1	Items 1 – 20	18 Statements	0.87	Very High	Reliability

Based on the reliability test, the Scientific Literacy Test (20 items) and the Sustainability Literacy Questionnaire (18 statements) both obtained a reliability coefficient of 0.87. According to the criteria, this score falls into the Very High category, indicating that the research instruments are highly reliable, consistent, and dependable for data collection.

Tabel 5. *Normality Results Test*

	Scientific Literacy		Sustainability Literacy	
	KolmogorovSmirnova	Sapiro-Wilk	KolmogorovSmirnova	Sapiro-Wilk
SMAN 4	0,11	0,23	,200*	0,082
SMAN 10	,200*	0,144	,200*	0,144
SMAN 14	0,97	0,44	,200*	0,377
SMAN 16	,200*	0,095	,200*	0,358

Based on the normality test using both the Kolmogorov-Smirnov and Shapiro-Wilk tests, the data for both Scientific Literacy and Sustainability Literacy across the four schools (SMA Negeri 4, SMA Negeri 10, SMA Negeri 14, and SMA Negeri 16 Bandar Lampung) show a significance value greater than 0.05 (indicated by values > 0.05 and marked with *). This demonstrates that all research data are normally distributed, thereby fulfilling the prerequisite requirements for parametric statistical analysis.

Tabel 6*. Hipotesis Result Test*

	Koefisien Korelasi (r)	Kontribusi (R2)	Sig.
SMAN 4	0,909 (Very hight)	82,7%	<0,01
SMAN 10	0,894 (Very hight)	79,9%	<0,01
SMAN 14	0,529 (sedang)	27,9%	<0,01
SMAN 16	0,241 (Low)	5,8%	0,047

Based on the correlation test results, the relationship between scientific literacy and sustainability literacy varies across the four schools. For SMA Negeri 4 and SMA Negeri 10, the correlation coefficient shows a Very High category ($r = 0.909$ and $r = 0.894$, respectively), with scientific literacy contributing significantly to sustainability literacy by 82.7% and 79.9%. For SMA Negeri 14, the correlation is in the Moderate category ($r = 0.529$), contributing 27.9%. Meanwhile, SMA Negeri 16 shows a Low correlation ($r = 0.241$), with a contribution of 5.8%. All schools show a significance value (Sig.) of < 0.01 and 0.047, which are less than 0.05, indicating that the correlations between the two variables are statistically significant.

The results of this study show that there are real differences and inequality in the science literacy ability of grade X students in Bandar Lampung City, especially in ecosystem materials in Biology lessons. Based on the data obtained, SN 10 (value 85.46) and SN 14 (value 81.38) are in the high-ability group, SN 4 is in the medium group (value 69.04), and SN 16 is in the lowest position (value 66.26). This difference supports previous theories suggesting that science literacy in urban schools has not been evenly distributed (Shofiyah & Faizah, 2018). This is greatly influenced by how students understand and process scientific concepts during classroom learning. In addition, schools with an established academic environment and competitive student input tend to be better prepared to develop students' critical thinking skills, which are at the core of science literacy itself.

If you look beyond the distribution of grades per student, you can see a very large gap between the highest and lowest grades, especially in SN 4, which has a grade range from 87.28 to 37.60. The striking gap in grades within the same school shows that students' understanding of science is seriously lacking. This fact strengthens Sari's theory previous studied that the main difficulty for students in mastering the Ecosystem material in Biology lessons is rooted in differences in each student's absorption capacity, which cannot be equalized or properly bridged during the learning process (Sudianto et al., 2024).

Ecosystem materials have complex, abstract, and demanding characteristics of systemic thinking. Students are not only required to memorize biotic and abiotic components but also to analyze energy flow, food chain dynamics, and the regulation of biogeochemical cycles. When teachers fail to address differences in learning speed through differentiated instruction, the gap in understanding among students in the classroom will widen drastically, leaving some students at the peak of achievement and others isolated in misunderstanding. In line with cognitive achievement, the affective dimension of students, as portrayed by science identity variables, also shows a linear, directly proportional trend. SN 10 reaffirmed its dominance with a very high average science identity score of 87.88.

This high science identity score indicates that students at the school already have a strong sense of belonging, emotional attachment, and confidence in their ability to act as "science agents" in social life. The importance of developing scientific identity is in line with the results of the investigation, which confirm the existence of a strong reciprocal relationship between scientific identity and cognitive learning outcomes (Maula et al., 2024). Students with a mature science identity will have a high intrinsic motivation to invest their intellectual energy in mastering biological material in depth because they view science as part of their self-representation. On the contrary, the findings in SN 4 revealed worrying data, with students' science identity scores mired at 56.09.

This low affective number indicates the presence of a thick barrier of internal motivational barriers among students. The fragile identity of science has a destructive impact on students' self-efficacy. This condition causes them to feel helpless (*learned helplessness*) and to consider themselves incapable of using or applying science to solve everyday practical problems (Sandrone et al., 2022). Students view science as a complicated, foreign subject, full of dead, memorization-based formulas, and having no point of contact with the reality of their lives. As a result of this loss of emotional attachment, students position themselves as passive spectators in biology classrooms, which leads to low scores on cognitive tests of science literacy in the field.

Comparative Analysis of Student Sustainability Literacy Profile Towards Global SDGs Targets

The evaluation of the bound variables revealed a portrait of students' sustainability literacy skills in Bandar Lampung City, marked by sharp contrasts among educational units. The extraordinary success recorded by SN 10, with an average sustainability literacy exceeding 92.36, indicates that students in the school have reached the ideal level of environmental awareness. At this level, students not only accumulate knowledge of the definition of nature conservation but also develop a solid value-system orientation, moral commitment, and ethical sensitivity to maintain the integrity of the biosphere's functions.

These impressive empirical findings are in line with the thesis formulated by previous studied that the evaluation of sustainability literacy, especially in the dimension of knowledge and the growth of environmentally friendly attitudes, will reach an optimal culmination point if it is consistently supported by the conditioning of a conducive, stimulating, and green-minded educational environment ecosystem (*Green School Environment*) (Sani, 2025; Solviana et al., 2024). However, the ideal portrait in SN 10 is inversely proportional to the extreme when the gaze is diverted to the condition of SN 16, which is down with an average sustainability literacy score of 56.00, and SN 4, which stands at 61.56.

This striking quantitative inequality is one of the important findings of this study. This fact reveals that the implementation of sustainable development education in the field has not been uniformly internalized and still exhibits acute sectoral inequality, even though all schools are under the legal umbrella and are required to achieve a uniform Independent Curriculum, conceptually, the structure of the Independent Curriculum is designed with high flexibility, which should be able to accelerate the improvement of student sustainability literacy in an inclusive manner through the Pancasila Student Profile Strengthening Project (P5) program with the theme Sustainable Lifestyle (Amalia & Diana, 2025).

At the practical level in the field, the effectiveness of this curriculum depends heavily on the adaptation process, technical readiness, and pedagogical competence of teachers in each educational unit. The challenge of optimizing sustainability literacy in some schools aligns with the view of (Wati et al., 2025). In the reality of learning, ecosystem materials and environmental changes are sometimes still studied only to fulfill textual cognitive requirements for exams, rather than being fully transformed into the formation of daily environmental ethics due to limited teaching time. If analyzed in more detail by indicator dimension, it can be seen that there is a gap between students' knowledge and their actual actions. Students obtained a fairly good percentage in the dimensions of Environmental Knowledge (78.5%) and Sustainability Mindset (74.8%).

However, these achievements have declined in the Systemic Skills (65.2%) and Real Action Disposition (60.5%) dimensions. This gap highlights the challenge of aligning understood knowledge with real, everyday actions (the Knowledge-Action *gap*). Students understand in theory and agree that the environment must be protected, but still need further guidance to apply this understanding through independent, real action. This condition shows that the applied biology learning model still predominantly focuses on conceptual understanding and needs to be expanded to encompass skills and behavioral habituation, which are the main targets of the SDGs agenda. As explained by previous studied the alignment of the SDGs agenda in biology learning demands a balance between understanding scientific concepts and fostering global awareness (Milati & Nugraheni, 2024). The results in SN 10 indicate that students are starting to get used to using systems thinking skills.

This skill is very important for students to understand the relationship between human activities and the long-term sustainability of ecosystems (Avianty & Purnawarman, 2025). Thus, students do not see environmental problems as stand-alone events but rather as part of a system of life in which problems affect one another. On the other hand, the challenges faced by SN 4 (with a minimum student score of 37.50) indicate the need to strengthen the supporting factors in schools. Emphasizing that the sustainability literacy profile of students in urban areas such as Bandar Lampung is greatly influenced by the formation of a culture of environmental care (*Environmental School Culture*) jointly designed by the school management (Khusniati & Yamtinah, 2024). Schools that have not had time to schedule practical activities outside the classroom can make students view ecosystem material as limited to memorization theory.

This challenge is also highlighted by previous studied in their discussion of the importance of developing contextual biology learning tools aligned with the environmental problems around students (Wahyuni et al., 2026). The data recorded in SN 14 present a unique characteristic: this school achieves a fairly good average score (81.38) but a fairly wide range of individual scores (minimum score of 61.99). This condition reflects the diversity of environmental awareness levels in the classroom, where some students are already independent in implementing green behavior, while others still need external motivation. These findings are relevant to the research by the previous studied which states that the relationship between understanding of the concept of ecosystems and actual behavior is not uniform, as it is influenced by family habits (Sofia, 2024).

Therefore, to bridge this diversity of abilities, it is necessary to restructure the learning model towards a more integrative approach, such as Project-Based Learning (PjBL) (Maulida et al., 2024). The PjBL model offers sufficient flexibility to engage and motivate students of different ability levels through collaborative group work. Meanwhile, the results at SN 16, with an average of 56.00 across variables, are valuable input for improving the quality of learning in the future. Equitable achievement in all these dimensions indicates that students' understanding of concepts, system skills, and green mindset is still in the early stages of development.

Reminding that sustainability education (*Education for Sustainable Development*) is an important basic capital for the younger generation to face future environmental challenges. In order for students' resilience to be stronger in facing environmental crises, the biology learning process is recommended to further integrate socio-scientific issues (*socio-scientific issues*). The learning process, which has been dominated by lecture-based methods, can be made more interactive. Bringing real issues that occur in the neighborhood (such as local waste management) into the classroom is highly effective at triggering critical reasoning and fostering a deep sense of environmental empathy in students (Prakoso & Nugraheni, 2024).

The Influence of Science Literacy on Sustainability Literacy

The inferential analysis in this study aims to see the extent of the linear influence between science literacy and student sustainability literacy in Bandar Lampung City. The results of statistical modeling cumulatively indicate a correlation coefficient R) of 0.592 (Medium category) and a Determination Coefficient (R2) of 0.350. This provides empirical evidence that students' science literacy contributes 35.0% to the development of their sustainability literacy. Theoretically, science literacy serves as the foundation of knowledge (*Cognitive Foundation*), which helps students understand natural mechanisms, cause-and-effect relationships, and ecological processes in the surrounding environment. This scientific knowledge is the main capital for students to build rational environmental awareness. These findings are in line with the thinking by previous studied that mastery of scientific literacy is one of the important keys for the younger generation to understand and respond to various complex global environmental issues (Alfiah et al., 2024).

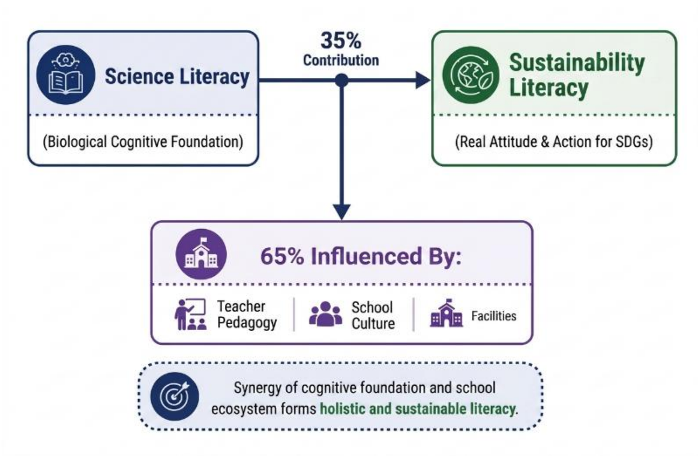

Figure 1. *Results of Science Literacy's Contribution to Sustainability Literacy*

Schools with a good average achievement in science literacy tend to show a similar pattern in sustainability literacy, as seen in the quantitative data in SN 10. This fact shows that a deep understanding of biological concepts of ecosystem materials makes it easy for students to internalize the values of sustainable development into their mindset. This process is in line with what was conveyed by the previous studied regarding the importance of cognitive transformation towards ecological awareness (Putri et al., 2025).

On the other hand, the existence of challenges in mastering basic science can be a limiting factor that limits students' ability to understand the importance of maintaining ecosystem balance in the long term. As explained by previous studied, the limitations of science literacy correlate with the lack of environmental sensitivity in making decisions related to environmental issues around them (Fuadi et al., 2020). For example, students who do not have a solid understanding of the concepts of material cycling and energy flow in biology will struggle to see the long-term impact of plastic waste disposal on the food chain.

Therefore, strengthening the relationship between these two variables is important for producing graduates who are not only academically intelligent but also responsible for the environment. If you look more closely at the comparative table by school, you will find that the variation in contributions is quite contrasting across educational units. In SN 14 and SN 10, the science literacy variable was a dominant factor, contributing 82.7% (R2 = 0.827) and 79.9% (R2 = 0.799) to students' sustainability literacy. This data shows that in schools with a conducive learning climate, mastery of science literacy in Biology subjects can function optimally as a driver of students' real-action abilities in line with the goals of the SDGs.

However, the results of regression modeling in SN 16 show a different pattern. A Coefficient of Determination (R2) value of 0.058 indicated that, in the school, science literacy accounted for 5.8% of students' sustainability literacy, while the remaining 94.2% was influenced by factors outside this research model. This phenomenon indicates that if biology learning remains dominant and focuses on memorizing theories for exam purposes, the application of science in daily life becomes less than optimal. In SN 16, students' biological knowledge does not seem fully integrated into practical actions. Students understand the components of the ecosystem for cognitive value needs, but when responding to real environmental issues, they tend to be more influenced by external factors outside of school, such as information from social media, family parenting, or norms in their circle of friends.

Analysis of Determinants of Synergies: School Pedagogy, Facilities, and Culture

The variation in contributions and differences in achievement between schools in Bandar Lampung City are suspected to be influenced by the interaction between students' internal factors and the school environment. The first internal factor that determines the condition of science's identity is students' personal motivation. The data show that schools with a strong level of science identity tend to understand biology material better.

Achievements in SN 10 are supported by a fairly good student science identity score (87.88). This is in line with the theory previous studied that a strong science identity can foster academic self-confidence (*Academic Self-Efficacy*) among students, enabling them to apply science in their daily lives (Restiani et al., 2024). Meanwhile, the achievement of science identity in SN 4, at 56.09, shows the need for a more contextual teaching approach so that students can see the linkage between biological sciences and their future, as well as global environmental issues related to the SDGs (Arfianti et al., 2025).The second external factor that determines the choice of learning method in the classroom is that the data analysis indicates that students' critical analysis skills across several schools still need improvement.

This is because the learning process of ecosystem material is generally still dominated by the lecture method and minimal field observation activities (field trips). Textual learning can make biological theories feel abstract to students. To optimize this, previous studied recommend implementing the Project-Based *Learning* (PjBL) model (Nuraini et al., 2023). Through the PjBL model, students are invited to identify local environmental problems around the school in groups and design real solution projects. This process actively trains students' critical reasoning, which is a core component of the science process skills that need to be developed. In addition, learning can be supported by interactive media, such as principles-integrated biology modules and *Education for Sustainable Development* (ESD), to foster students' ecological empathy (Andira et al., 2026).

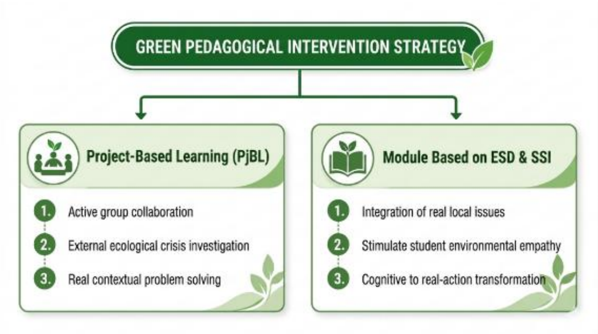

Figure 2. *Biology Learning Strategies with Integrated Approaches Education for Sustainable Development (ESD)*

The third external factor, no less important, is the availability of supporting facilities and the development of an *environmental school culture*. The difference in biology laboratory facilities and the existence of school policies regarding environmental management (such as single-use plastic waste reduction programs or compost management) provide a varied *learning experience* for students. Schools that prioritize eco-friendly programs and supportive facilities (such as those in SN 10 and SN 14) create a conducive academic atmosphere.

The inculcation of environmental ethics in schools serves as a hidden curriculum that effectively shapes students' character. Sustainability values are no longer just memorized from textbooks, but implemented in daily behavior because they have become part of the habit in school. This is reinforced by previous studied, which concludes that the development of a school culture that supports green literacy is highly efficient in helping students transform theoretical knowledge into consistent, tangible actions (Masril et al., 2021). Overall, the results of this study confirm that strengthening science literacy will optimally develop sustainability awareness if supported by a comprehensive school ecosystem. A solid synergy is needed between students' understanding of science, the accuracy of teachers' learning models, and the habituation of environmental care characters in schools in order to produce a young generation who are intelligent, literate, and ready to contribute to environmental conservation towards the SDGs agenda.

Research Implications for Sustainable Biology Learning Policy

The findings in this study have strategic implications for curriculum development, teachers' teaching practices, and environmental governance in high schools in Bandar Lampung City. Theoretically, the positive contribution of 35.0% of science literacy to sustainability literacy is shown by (Parisu et al., 2025). Understanding scientific material is closely related to the formation of a student's character. The implication is that the development of the biology curriculum is recommended to further integrate pure science materials with the SDGs agenda. The synchronization of these teaching materials is important so that every aspect of biology learning, especially materials related to ecosystems, can help students master the analysis of the global sustainability system from an early age.

At the classroom learning level, this study provides an empirical overview of the importance of developing active and contextual learning models to build students' science identities. Biology teachers can serve as facilitators who optimize the school environment as a real source of ecological learning (Arbadilah et al., 2025). The implications of this teaching encourage the strengthening of teachers' competence in compiling authentic assessment instruments. The assessment is expected not only to measure cognitive mastery through written exams but also to evaluate the development of process skills, environmental care attitudes, and collaborative real-action projects carried out by students.

Finally, the institutional implications show that classroom learning innovation needs to be supported by the formation of a culture and ecosystem aligned with the school (Handoko et al., 2024). School management plays an important role in developing regulations that support the habituation to sustainable development values. Policies such as school green areas, plastic waste reduction programs in canteens, and the provision of waste-sorting facilities can serve as practical educational resources for students.

The school is expected to be a model of a sustainable environment, where students can see and practice the ecosystem biology material they learn in the classroom directly in their daily lives. Through the harmony among curriculum content, teacher learning methods, and school culture, the vision of producing a generation that is literate and cares about environmental sustainability can be realized optimally (Ranisa et al., 2025).

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Conclusion

This study aimed to examine the influence of science literacy on the sustainability literacy of senior high school students in Bandar Lampung City in Biology learning. The findings revealed that science literacy had a positive and significant effect on sustainability literacy, contributing 35.0% to students' sustainability literacy. This result highlights that a strong understanding of biological concepts, particularly ecosystems, provides an essential foundation for developing students' awareness of environmental issues and the Sustainable Development Goals (SDGs). However, the magnitude of this contribution varied across schools, suggesting that learning climate and school culture play important roles in strengthening sustainability literacy. These findings reinforce the theoretical relationship between the cognitive domain (science literacy) and the affective and behavioral domains (sustainability literacy), emphasizing the need to integrate environmental and character education into Biology instruction. The study was limited by the use of purposive sampling involving only four public senior high schools in Bandar Lampung, restricting the generalizability of the findings. Future research should investigate other factors influencing sustainability literacy, including teacher pedagogy, family environment, school culture, and social media exposure, while exploring project-based learning and authentic assessment to enhance students' environmental responsibility.

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