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Environmental Literacy and Scientific Communication in Indonesian Primary Schools: Teachers' and Students' Perceptions

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Abstract

Although scientific communication and environmental literacy are increasingly recognized as essential skills for addressing global ecological issues, empirical data remain scarce in many educational environments, particularly in Indonesia. The purpose of this study is to evaluate the role of instructional modules in fostering the development of these competencies in primary schools and to investigate how instructors and students perceive these competencies. Validated questionnaires (CVI = 0.89; $\alpha = 0.91$) were used to collect quantitative data from 236 teachers and 456 pupils, employing an explanatory sequential mixed-methods design. Semi-structured interviews were then conducted to enhance understanding. According to survey data, students perform poorly in advanced skills, such as graph construction (51.9%). Still, they are highly engaged in basic environmental practices (e.g., proper waste disposal, at 98.9%) and foundational communication skills (e.g., report writing, at 87.2%). Teachers showed overwhelming support (97.0%) for creating better modules, despite reporting a limited supply of pertinent instructional resources (62.6%). Strong relationships between instructors' and students' competences are shown by correlation studies, especially between teachers' environmental literacy and students' comparable skills ($r = 0.903$). The results show that integrating ecological knowledge with communication skills requires well-designed modules. In addition to providing empirical data from Indonesia, this study emphasizes the need for comprehensive, context-responsive teaching resources to enhance 21st-century skills and sustainability education.

Keywords: Environmental Literacy, Perceptions, Primary School, Scientific Communication.

Introduction

There are big environmental problems in the twenty-first century, such as climate change, loss of biodiversity and problems with trash. These problems show how important it is to teach people about the environment and how to talk about science (1-4). Environmental literacy helps people learn and behave responsibly, whereas scientific communication helps people explain problems, discuss solutions and make their case (3, 5). These abilities help students deal with environmental problems and make a real difference in society. There is more and more demand for schools to include sustainability and communication in their lessons. Environmental literacy gets pupils involved with real-world problems like climate change, trash reduction and conservation (6). They can share their thoughts through reports, presentations and pictures thanks to scientific communication. These abilities work together to help kids learn, feel more confident and solve problems, which makes sure they can use what they know to deal with environmental problems (7). Environmental literacy includes the knowledge, attitudes and abilities that help students deal with environmental issues while also improving their ability to think critically and solve problems (8-12). Scientific communication is the process of getting ideas across through writing, speaking and pictures. It helps students explain their ideas clearly and effectively (13-15). To develop these talents and strengthen 21st-century skills, it is important to have well-designed instructional modules that are in line with learning goals (16, 17). Even though environmental literacy and scientific communication are highly regarded, research indicates considerable constraints (18). Studies sometimes concentrate on certain nations or places, such as Peru, Colombia, China and Rwanda, which complicates generalization and frequently depend exclusively on polls (19). Many

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studies are still just ideas, especially in higher education and they haven't been tested in real life (20, 21). Thus, there exists a distinct deficiency in comprehending how these competences are regarded and implemented by educators and learners in various contexts, especially in Indonesia. Studies demonstrate that students' scientific communication skills are usually average and they have trouble saying and writing down ideas (22). More thorough research is needed to find out how instructional modules may best help people in Indonesia and other places improve these skills (23, 24). Indonesia needs pupils who are ecologically literate and good at scientific communication right away. These students should have access to the right modules and teaching resources (25, 26).

Studies show that environmental literacy involves more than just understanding information. It also includes attitudes and actions that promote living in ways that are good for the environment (1-3). Evidence indicates that it encompasses cognitive, emotive and behavioral components that facilitate individuals in taking tangible actions to save the environment. (9, 10). In Latin America, the focus is on integrating environmental education into school curricula and ensuring it aligns with sustainability goals (19). In Latin America, the focus is on integrating environmental education into school curricula and ensuring it aligns with sustainability goals (18, 19). Limited international studies underscore Indonesia's pressing requirement for research on context-specific sustainability education (20, 21).

Today's students need to be able to clearly express difficult scientific topics through writing, speaking and pictures (13, 15). Along with teamwork, critical thinking and creativity, scientific communication is becoming increasingly important in the 21st century (23). Research indicates that proficient communication skills enable pupils to disseminate information, navigate conflicts and collaborate on problem-solving (24). But systematic reviews indicate that communication in science classrooms is generally only average and many students struggle to express their thoughts in both writing and speech (22). Blended learning can improve communication and higher-order thinking, but data visualization and visuals are still not used very often (7, 22). Overall, there isn't much proof from Indonesia yet.

Many people consider that instructional modules are useful for making sure that learning is in line with 21st-century abilities, including critical thinking, problem-solving and good scientific communication through reports, presentations and data visualization (16, 17). They also assist pupils in dealing with real-world problems like climate change, cutting down on waste and protecting the environment. However, many teachers, especially in less developed areas, don't have tools that can be used in a variety of situations (6). Even still, most modules are mostly ideas or not well-tested and they often don't take into account the views of teachers (25, 26). This study fills that gap.

The researchers restructured previous studies into three frameworks: environmental literacy as a multidimensional competency, scientific communication as a 21st-century talent and instructional modules that connect them. They put together findings from several places and pointed out problems and limitations, such as geographic boundaries and survey-only approaches. Integrative critiques pointed out concepts that hadn't been tested and evidence that was hard to find. These gaps made it clear what the study was about. Environmental literacy includes information, thinking, feelings and actions, whereas scientific communication includes writing, speaking and seeing skills, which makes measurement and analysis more accurate.

Environmental literacy (EL) is an upstream competency that combines information about the environment, cognitive skills, attitudes and feelings and actions that benefit the environment shown in Figure 1.

Recent studies define environmental literacy (EL) as the combination of knowledge, capability and readiness to act. Scientific communication (SC) turns EL into things that can be seen and heard, like writing, speaking, debating and showing data in a way that makes sense (27). Social capital affects how much EL affects pro-environmental involvement and repeated communication helps learning. Instructional modules help both EL and SC by giving them practical tasks and feedback (28, 29). This is in line with the focus of education for sustainable development on action and communication (30).

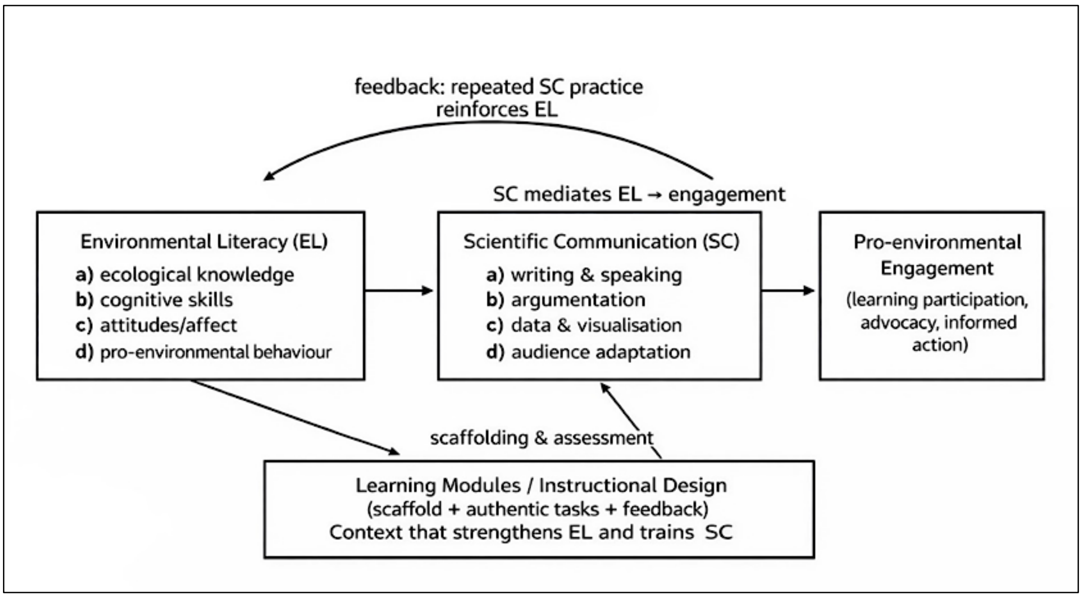

Figure 1: The Interplay between Scientific Communication and Environmental Literacy

Thus, the research objectives are to examine teachers' and students' perceptions of environmental literacy and scientific communication, assess the relationship between these competencies and identify the instructional module supports needed to strengthen their integration in Indonesian primary schools.

Methodology

Research Design

The Methodology employs an explanatory sequential mixed-methods design. First, the quantitative phase (surveys of teachers and students) was conducted to identify general trends, skill levels and links between environmental literacy and scientific communication. The qualitative phase (semi-structured interviews) was then used to explain the statistical results, put them in perspective and delve further into them, especially where there were gaps in skills and modules. This order was chosen to ensure breadth precedes depth and to promote integrated interpretation through a joint display, which aligns with the study's goal and the mixed-methods logic as a whole (31). Researchers can triangulate data using this design, ensuring both the depth and breadth of the study. To gather quantifiable trends and investigate complex viewpoints, surveys and interviews were combined (32).

Population and Sample

Indonesian primary school teachers and kids made up the research population. So, the population and Sample used a non-probability, multistage sampling approach. First, the 20 elementary schools were chosen on purpose based on their level (primary), whether they had authorization from the administration and whether they were willing to participate. This was done to ensure that the schools were distinct from one another. These pupils were selected from fifth-grade classes at 20 elementary schools. With 230 female students and 226 male students, the student body's gender distribution was fairly balanced. Second, teachers who met the study criteria (certified and actively teaching) and Grade 5 students who were available during data collection were recruited from each designated school using convenience/accessible sampling. Researchers also made it clear how many students they wanted to study [500] and how many legitimate responses they got [456]. This varied Sample provided a solid foundation for investigating educators' and learners' viewpoints on scientific communication and environmental literacy.

Research Instrument

A structured questionnaire was used to gather data for this study, which aimed to gauge teachers' and students' opinions on scientific communication and environmental literacy. To adequately capture the multifaceted nature of these competencies—which include cognitive knowledge, affective dispositions and behavioural practices—the instrument was carefully designed and created. The questionnaire underwent construct validity and content validity tests to ensure its robustness.

To ensure that every item was both empirically relevant to the Indonesian educational context and theoretically linked with the constructs under inquiry, expert reviewers were engaged (31).

The validation process demonstrated strong outcomes. Expert judgment was used to evaluate content validity, yielding a Content Validity Index (CVI) of 0.89, indicating that most items were deemed highly relevant. Factor analysis was used to examine construct validity further and the results showed that the questions grouped correctly into the targeted aspects of scientific communication and environmental literacy. To ensure the instrument's internal consistency, a reliability analysis was conducted. Excellent reliability was confirmed by the overall Cronbach's Alpha coefficient of 0.91, which exceeded the suggested cutoff of 0.70 (33). With an alpha of 0.88 for environmental literacy items and 0.86 for scientific communication items, subscale dependability was likewise quite high.

Data Collection

Surveys and semi-structured interviews were employed as complementary methods. By asking participants to answer a series of structured questions, the survey generated quantifiable data that enabled statistical analysis of their viewpoints. Semi-structured interviews were carried out with a subset of respondents to enhance the insights. This method enabled the examination of delicate topics, individual experiences and contextual elements that surveys were unable to capture fully (34). Four main areas were covered by the interview questions, which were derived from the survey items:

(a) students' perspectives on environmental literacy and scientific communication;
(b) teachers' perspectives on the same competencies;
(c) the relationship between environmental literacy and scientific communication; and
(d) the prototype of instructional models appropriate to these competencies.

Data Analysis

The analysis consisted of two stages. SEMPLS software was used to analyze quantitative survey data, enabling statistical analysis of correlations and trends. Thematic analysis was employed to examine qualitative interview data, aiming to uncover deeper meanings and recurring patterns in participants' responses. Lastly, the researchers combined statistical results with qualitative insights to provide a comprehensive interpretation by integrating both datasets using a joint display approach (35, 36). This integration enhanced the validity and applicability of the findings by ensuring that the study not only measured competences but also contextualised them within the participants' lived experiences.

Researchers incorporated a specific ethics statement that delineated institutional approval, school authorization, parental informed consent and student assent for all primary school participants. The study elucidates voluntary participation, anonymity and the management of confidential data to meet the ethical standards required for research involving children in Indonesia.

Results

Results of Teachers' Perceptions of the Importance and Integration of Environmental Literacy, Scientific Communication and Module Requirements

The questionnaire covers three topics: module requirements, scientific communication and environmental literacy. Items 1 through 5 evaluate eco-friendly practices, including energy conservation, waste management and cleaning. While questions 11–15 examine instructional resources and provide a comprehensive picture of student competencies and instructor tactics for improvement, items 6–10 assess communication skills.

The students' involvement in scientific communication and environmental literacy is clearly demonstrated by the questionnaire answers in Table 1. Strong cleaning and energy-saving habits are evident in the results for environmental literacy (items 1–5). Students routinely sweep the floor, according to nearly all respondents (99.57%, SD = 0.06523) and they consistently dispose of their waste appropriately, as indicated by 94.04% (SD = 0.23720). With 89.36% involvement (SD = 0.30899), turning off unused lights is another common practice.

Table 1: Results of Environmental Literacy, Scientific Communication and Module Requirements

	N	Range	Minimum	Maximum	Mean	Std. Deviation	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
Sweep the floor	235	1.00	0.00	1.00	0.9957	0.06523	-15.330	0.159	235.000	0.316
Consistently throwing trash in the bin	235	1.00	0.00	1.00	0.9404	0.23720	-3.745	0.159	12.131	0.316
Regularly water the garden plants	235	1.00	0.00	1.00	0.7574	0.42954	-1.209	0.159	-.543	0.316
Turn off lights when the room is unused	235	1.00	0.00	1.00	0.8936	0.30899	-2.570	0.159	4.643	0.316
Encouraged others to keep clean	235	1.00	0.00	1.00	0.9277	0.25960	-3.323	0.159	9.120	0.316
write Reports for group tasks	235	1.00	0.00	1.00	0.8723	0.33442	-2.246	0.159	3.070	0.316
able to Create tables in their reports	235	1.00	0.00	1.00	0.6638	0.47341	-0.698	0.159	-1.526	0.316
Generate graphs effectively	235	1.00	0.00	1.00	0.5191	0.50070	-0.077	0.159	-2.011	0.316
Confident presenting in class	235	1.00	0.00	1.00	0.8596	0.34817	-2.083	0.159	2.360	0.316
Use tools like images during presentations	235	1.00	0.00	1.00	0.8596	0.34817	-2.083	0.159	2.360	0.316
Taught environmental literacy and communication skills	235	1.00	0.00	1.00	0.8213	0.38394	-1.688	0.159	0.856	0.316
Teaching materials for these subjects	235	1.00	0.00	1.00	0.6255	0.48502	-0.522	0.159	-1.742	0.316
Module thorough enough for these topics	235	1.00	0.00	1.00	0.6000	0.49094	-0.411	0.159	-1.847	0.316
Teaching effectively developed these skills	235	1.00	0.00	1.00	0.7106	0.45443	-0.935	0.159	-1.136	0.316
Support Creating a new teaching model for this	235	1.00	0.00	1.00	0.9702	0.17036	-5.568	0.159	29.246	0.316
Valid N (listwise)	235									

At 92.77%, encouraging others to maintain cleanliness is likewise quite powerful. However, only 75.74% of pupils consistently water garden plants (SD = 0.42954). Asymmetry in these behaviours is suggested by the skewness and kurtosis values, indicating areas that need specific reinforcement. Students demonstrate moderate to high competency in fundamental skills related to scientific communication (items 6–10). Report writing is accomplished by 87.23% (SD = 0.33442) and presentation confidence is high at 85.96% (SD = 0.34817). At 85.96%, the use of graphics in presentations is similarly frequent. However, more sophisticated abilities are weaker: just 51.91% of respondents (SD = 0.50070) are proficient at making graphs, whereas 66.38% (SD = 0.47341) report proficiency at constructing tables. Regarding the module requirements (items 11–15), only 62.55% of teachers report having appropriate materials (SD = 0.48502), despite 82.13% of instructors having experience teaching these abilities (SD = 0.38394). The current modules have a rating of 71.06% (SD = 0.45443) for teaching effectiveness and 60.00% (SD = 0.49094) for thoroughness. Notably, 97.02% of educators (SD = 0.17036) are in favour of creating new models, indicating a significant demand for improved tools and techniques.

Results of Students' Perception on the Role of Environmental Literacy and Scientific Communication

Strong eco-friendly practices are highlighted in the student questionnaire: only 67.47% regularly water plants, yet 98.90% correctly dispose of waste and 94.29% turn off unneeded lights. In scientific communication, 85.93% create tables and 83.74% confidently present; nevertheless, only 69.23% describe themselves as proficient in creating graphs.

The questionnaire responses in Table 2 highlight students' environmental literacy and scientific communication skills and also suggest opportunities for improvement. Nearly all students (98.90%, SD = 0.10437) regularly dispose of trash appropriately in environmental literacy (items 1–5) and 94.29% (SD = 0.23237) turn off unnecessary lights, demonstrating a great knowledge of cleanliness and energy conservation. Peer pressure to maintain cleanliness is also prevalent (92.77%, SD = 0.25623). However, only 75.74% (SD = 0.42954) of the water garden plants are watered regularly, indicating a lower level of interaction with the natural world.

Table 2: Results of Environmental Literacy and Scientific Communication from Students

	N	Range	Minimum	Maximum	Mean	Std. Deviation	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
Sweep the floor if it's dirty	455	1.00	0.00	1.00	0.9714	0.16678	-5.678	0.114	30.375	0.228
Always throw trash in the bin	455	1.00	0.00	1.00	0.9890	0.10437	-9.412	0.114	86.977	0.228
The habit of watering the plants in the garden	455	1.00	0.00	1.00	0.6747	0.46899	-0.748	0.114	-1.446	0.228
Always turn off the lights when the room isn't being used	455	1.00	0.00	1.00	0.9429	0.23237	-3.828	0.114	12.713	0.228
Encouraged others to keep things clean	455	1.00	0.00	1.00	0.9297	0.25598	-3.372	0.114	9.411	0.228
Write reports for group assignments	455	1.00	0.00	1.00	0.8989	0.30179	-2.655	0.114	5.073	0.228
Able to create tables in your group reports	455	1.00	0.00	1.00	0.8593	0.34805	-2.074	0.114	2.312	0.228
Make graphs effectively	455	1.00	0.00	1.00	0.6923	0.46205	-0.836	0.114	-1.307	0.228
Confident presenting in front of the class	455	1.00	0.00	1.00	0.8374	0.36944	-1.834	0.114	1.371	0.228
Use media, like images, when giving presentations	455	1.00	0.00	1.00	0.8352	0.37144	-1.813	0.114	1.291	0.228
Valid N (listwise)	455									

Students demonstrate strong foundational skills in scientific communication (items 6–10): 85.93% (SD = 0.34805) can create tables, 83.74% (SD = 0.36944) present their work confidently and 85.96% (SD = 0.34820) effectively use images in presentations. However, just 64.44% (SD = 0.47352) are proficient in creating graphs, indicating a lack of advanced skills. These results underscore the need for targeted training in data visualisation and more comprehensive environmental practices. Still, they also imply the importance of strong eco-friendly habits and effective communication fundamentals.

Skewness and kurtosis were used not as the primary basis for statistical inference, but to elucidate response distribution patterns (e.g., a ceiling effect in basic skills and a more equitable distribution in advanced skills). Since the items are dichotomous, the key meaning is still about proportions and mean scores. We also made the tables easier to read by moving specific distribution information to the appendix and clarifying its effects in the discussion section. This version makes it clearer that the descriptive statistics support the study's conclusions rather than leading to them.

Significance and Nature of the Correlation between Teachers' and Students' Perceptions of Environmental Literacy and Scientific Communication

Four key factors are examined in this connection study: GEL (environmental literacy for teachers), GSC (scientific communication of teachers), SEL (environmental literacy for students) and SSC (scientific communication for students). The study highlights how teachers and students collaborate to create a learning environment that prioritizes effective communication and environmental awareness. Students' competencies in comprehending environmental issues (SEL) and expressing their thoughts through scientific communication (SSC) are shaped by teachers' environmental literacy and their capacity to communicate scientific concepts (GEL and GSC). The study demonstrates how the synergy between Teacher and student competences can enhance the overall impact of environmental education by examining the connections between these factors shown in Figure 2.

Using quantitative data, this study examines the relationships among GEL (teachers' environmental literacy), GSC (teachers' scientific communication), SEL (students' environmental literacy) and SSC (students' scientific communication). The significant impact of teachers' environmental literacy on pupils' knowledge and abilities is demonstrated by the substantial positive correlation of 0.903 between GEL and SEL. Similarly, a correlation of 0.787 between GSC and SSC indicates that teachers' communication skills significantly influence students' ability to articulate environmental concepts. It's interesting to note that whereas SEL and SSC exhibit only a modest correlation of 0.158, indicating little interaction between students' literacy and communication, GEL and GSC show no discernible association (p = 0.000).

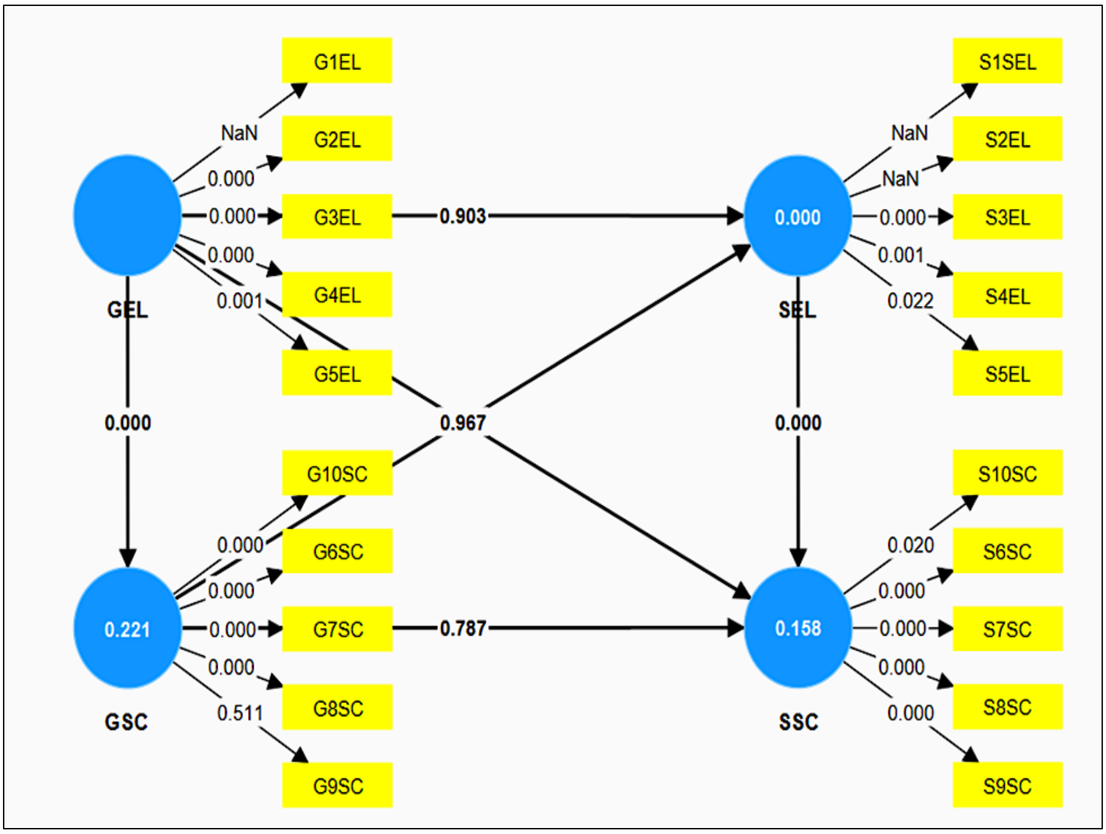

Figure 2: Results of the Correlation between Teachers' and Students' Perceptions of Environmental Literacy and Scientific Communication

To improve environmental education, these findings emphasize the need for comprehensive modules that support all four competences while balancing teacher preparation and student practice. EFA (principal-axis, by subscale) showed that the sample size was good to fair: KMO varied from 0.534 (Teacher EL) to 0.698 (Student SC). Bartlett's tests were significant for all subscales ($\chi^2(10) = 63.22–165.80$, p<.001), which means that the factors could be separated. The absolute loadings for teachers were between 0.025 and 0.897, while for students were between 0.047 and 0.563. There was 23.96% explained variance for Teacher EL, 29.22% for Teacher SC, 16.55% for Student EL and 24.50% for Student SC.

The Interconnection between Environmental Literacy, Scientific Communication and Module Requirements

To understand their combined impact on environmental education, this correlational study examines the dynamic relationships among GEL (Environmental Literacy for Teachers), GSC (Scientific Communication of Teachers) and GMR (Module Requirement). Instructors' capacity to teach and help pupils understand urgent ecological issues is grounded in environmental literacy and scientific communication equips them with the tools to convey this information effectively.

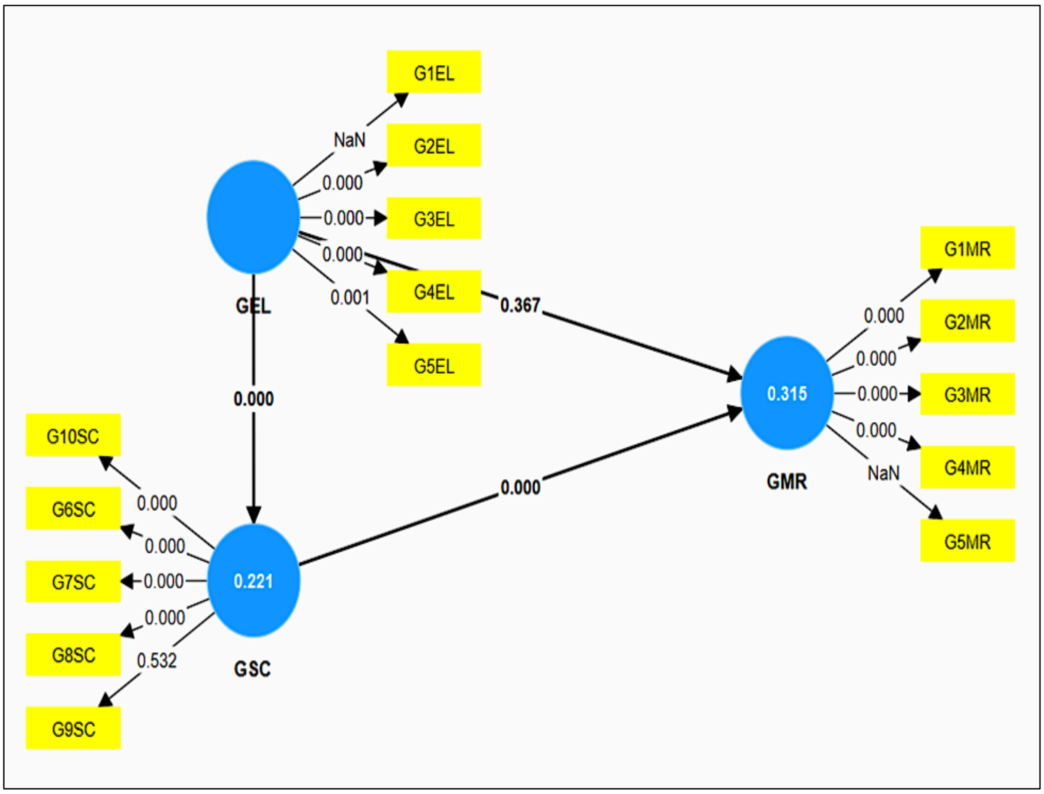

Figure 3: Results of the Interconnection Between Environmental Literacy, Scientific Communicationand Module Requirements

The foundation for smoothly incorporating these two components into teaching methods is provided by well-organised module requirements. The study aims to determine how teachers' perceptions of module requirements align with their environmental literacy and communication skills and how this alignment affects the overall quality and efficacy of environmental education by analysing the relationships among these variables shown in Figure 3.

This correlation analysis provides valuable insights into the relationships between GMR (module requirements), GSC (teachers' scientific communication) and GEL (teachers' environmental literacy). GEL and GMR had a moderately positive association of 0.367, according to the data, indicating that teachers who are more environmentally literate are more likely to understand the value of complete, flexible modules. It's interesting to note that there was no association ($p = 0.000$) between GEL and GSC, suggesting that teacher preparation is lacking and that environmental literacy does not always translate into effective communication abilities. Similarly, there is no discernible correlation between GSC and GMR ($p = 0.000$), indicating that communication skills do not directly influence views of module requirements. Nonetheless, one sub-variable, G8SC, shows a comparatively large correlation of 0.532 with GSC, indicating that some aspects of communication, such as successfully presenting data, are more closely related. These results highlight the need for literacy- and communication-integrated programs to improve teachers' abilities.

Researchers currently use Pearson's product-moment correlation to analyze composite EL and SC scores. They now give accurate p-values

(instead of p = 0.000) and 95% confidence intervals for each coefficient. Researchers included a concise justification for test selection and assumptions, enhancing statistical transparency, interpretative accuracy and the reproducibility of the correlation study across all reported models.
The KMO values for the teacher items using EFA (principal-axis) were 0.534 (EL), 0.638 (SC) and 0.765 (MR), indicating they were mostly good. The Bartlett tests were significant for all subscales ($\chi^2(10)$ = 87.98, 165.80 and 353.31; all $p<0.001$). The factor loadings were 0.044–0.897 for EL, 0.025–0.812 for SC and 0.291–0.792 for MR. The explained variances were 23.96%, 29.22% and 44.49%, indicating that the MR structure is the strongest and the EL/SC structure is still understandable but weaker.

The Ways of Environmental Literacy, Scientific Communication and Module Requirements Are Interconnected

Students' testimonies demonstrate how environmental literacy is integrated into their daily lives, reinforced through educational modules and expressed in scientific communication. In addition to being acts of cleaning, sweeping floors, correctly disposing of waste and watering plants were regarded as measures to maintain life, prevent pollution and provide comfort. While some students acknowledged watering plants at school only, when necessary, others took care of flowers or veggies at home, demonstrating how institutional modules can fill gaps in household chores. These actions demonstrate that environmental consciousness is lived rather than merely taught and the educational setting provides a structured framework that ensures even reluctant students practice stewardship. Simultaneously, students' thoughts about shutting off lights to conserve power or motivating classmates to maintain a clean classroom demonstrate how environmental knowledge transcends individual behaviours into group accountability.
The way scientific communication develops from these modules, connecting academic discourse with environmental practice, is equally significant. Although the majority acknowledged that they had not yet used graphs or digital media, students described writing group reports, creating tables to monitor compost progress and presenting their findings to peers. Although the module required them to participate and present their work, their comfort with oral presentations varied, with some feeling confident and others afraid. The interdependence of the three domains is illustrated by this cycle, which consists of modules that call for environmental projects, students documenting and presenting them and communication that strengthens literacy. The form is provided by scientific communication, module requirements provide the structure and the substance is provided by environmental literacy. Together, they develop students who not only behave sustainably but also clearly explain their activities, equipping them to fulfil higher levels of civic and scientific responsibility shown in Figures 4A and 4B.

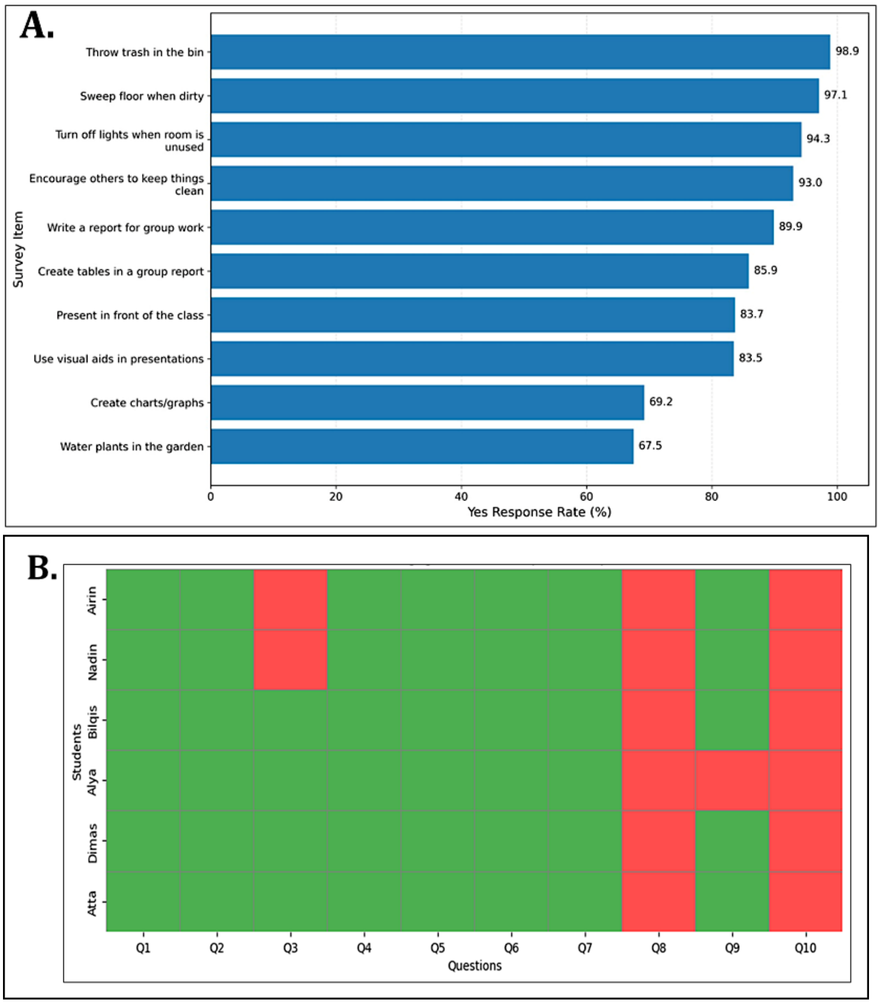

Figure 4: Student Engagement in Through-cut and Heatmap. (A) Engagement Level (B) Engagement Category

Each student's answers to all 10 questions are displayed on the heatmap, with their responses categorized as either engaged (green) or not engaged (red). While scientific communication (Q6–Q8) demonstrates strong participation in report writing and table creation, a glaring gap remains in graph creation. However, it is evident that almost all students consistently engage in environmental literacy practices (Q1–Q5). The majority of students are comfortable giving oral presentations (Q9–Q10), but very few utilise sophisticated media, such as PowerPoint or LCD.

These results are combined into three domains in the through-cut bar chart. With almost all pupils participating, environmental literacy scores are the highest. The lack of graphs weakens the somewhat strong scientific communication, which is fueled by report writing and tables. The lowest engagement percentage is in presentation skills, indicating minimal media use and confidence gaps. When taken as a whole, these illustrations show how scientific communication gives the form, environmental literacy offers the content and module requirements provide the structure of the interrelated cycle. The teacher interviews demonstrate the intimate connections between scientific communication, environmental literacy and module requirements in classroom practice, creating a cycle that supports student behaviour and learning shown in Figures 5A and 5B.

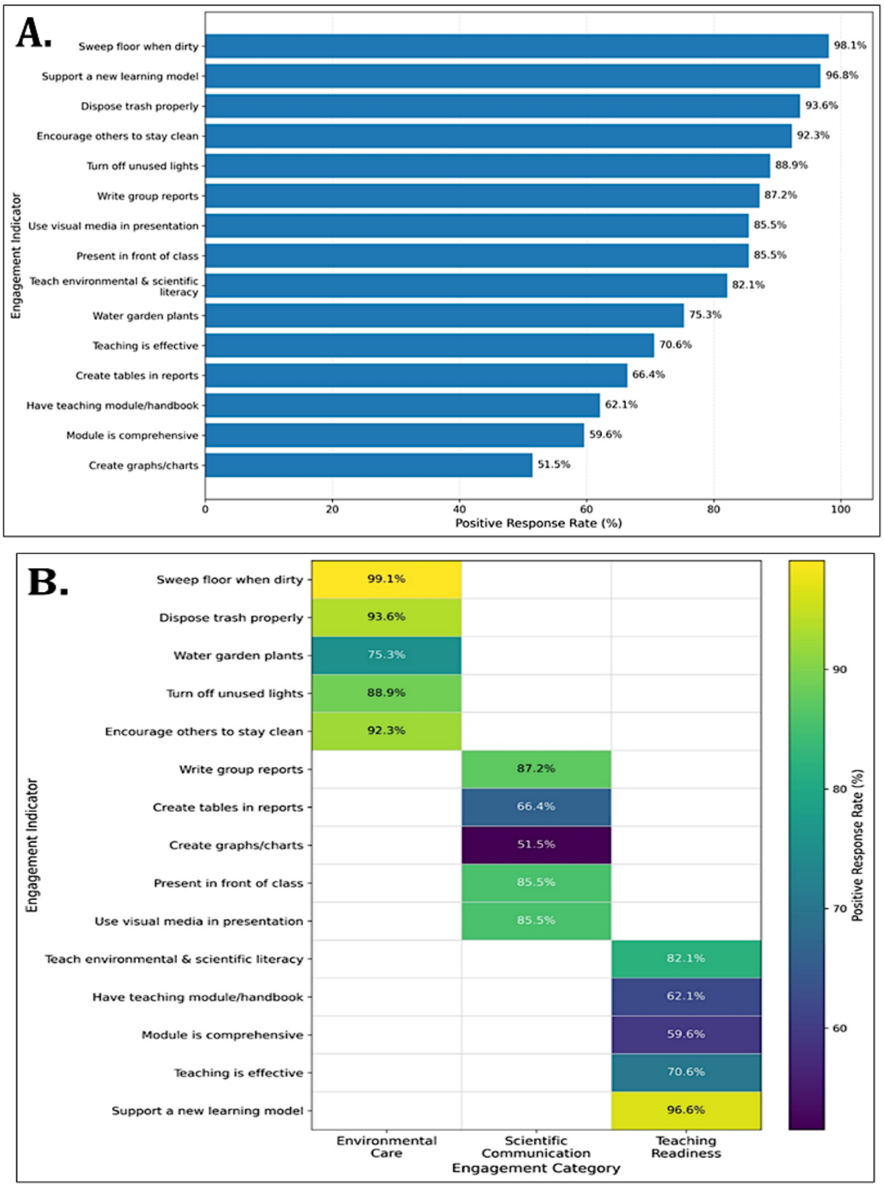

Figure 5: Teacher Response on Connections Between Scientific Communication, Environmental Literacy and Module Requirements. (A) Throughcut: Engagement level, (B) Heatmap: Engagement category

In Figure 5, environmental literacy is developed through everyday activities such as sweeping floors, correctly disposing of waste, watering plants and conserving electricity. These activities are frequently coordinated through class assignments or school initiatives. Teachers and parents collaborate to develop these behaviours, which are not only useful but also portrayed as moral and civic obligations. Students are required to write reports, create tables and present findings in scientific communication, thereby turning these environmental practices into academic skills. This is especially true for P5 projects, such as plant classification or compost-making. Graph-making remains uncommon, despite the prevalence of tables and straightforward narratives, suggesting a disconnect between environmental practices and quantitative communication. This approach is further extended by presentation skills, where students explain their work verbally, occasionally using Canva, videos, or posters; however, media usage and confidence vary. The structural framework is provided by module requirements, which compel students to record and report their environmental efforts as they are incorporated into courses such as PKN, IPAS and PLH. To ensure that students practice sustainability while learning to explain it academically, teachers create lesson plans, LKPDs and contextualised modules that link environmental literacy with communication tasks.

In this sense, scientific communication provides the form, environmental literacy offers the content and modules provide the structure, resulting in a comprehensive pedagogy in which each component supports the others and equips students to meet broader civic and educational norms.

This study delineates engagement thresholds, categorizing each dichotomous item as 1 = engaged and 0 = not engaged and quantifying domain-level engagement as the percentage of "1" replies (high ≥80%, moderate 60–79%, low <60%). The heatmap visual coding was derived directly from binary data at the item level. The through-cut bars, on the other hand, group scores by domain (EL, SC, presentation). These graphics help with analysis by showing individual response patterns, clusters and bottlenecks that aren't as clear in summary tables.

Discussion

The results show that students actively engage in fundamental environmental behaviours, including sweeping floors, properly disposing of trash and shutting off unused lights. These actions suggest that students' everyday routines already incorporate positive attitudes toward sustainability, reflecting the early development of environmental literacy. Nonetheless, inconsistent behaviour—especially when it comes to watering plants—demonstrates that ecological responsibility varies across different practice domains. This supports the notion that environmental literacy is intrinsically complex, with behavioural, affective and cognitive components (9, 10). Even if the frequency of these activities varies, the general pattern shows that, with the right support, kids can develop eco-friendly habits.

Theoretically, these findings highlight the importance of incorporating environmental literacy into daily tasks, rather than viewing it as an abstract concept. From a practical standpoint, this means schools should provide interventions that extend beyond classroom education and include experiential learning opportunities, such as gardening programs, recycling campaigns, or energy-saving initiatives. These strategies are consistent with earlier studies that highlight how incorporating environmental education into school curricula can promote sustainable development (18).

Additionally, the study demonstrates that students are moderately to highly proficient in fundamental scientific communication abilities, such as drafting reports and giving confident presentations. However, more sophisticated skills are still lacking, particularly in data visualisation using tables and graphs. This disparity suggests that although students are comfortable communicating concepts both orally and in writing, they struggle to convert data into analytical or graphical formats. These results are consistent with previous research showing that science students often possess only mediocre communication skills and struggle to express themselves both verbally and in writing (22). Theoretically, this highlights the dual nature of scientific communication, which requires both language proficiency and the ability to convey complex material in understandable representations (13, 15). Practically speaking, the findings necessitate focused teaching methods that enhance data literacy and visualisation—skills that are becoming increasingly crucial in the twenty-first century. While blended learning has been shown to improve critical thinking and communication, the current study suggests that students' ability to convey scientific discoveries remains limited in the absence of a clear focus on graphical competencies.

Teachers reported the availability and sufficiency of current resources for scientific communication and environmental literacy only moderately, despite their strong support (97.02%) for creating new teaching methods. In line with earlier research highlighting their relevance in promoting critical thinking and problem-solving, this discontent emphasises the necessity of well-designed instructional modules (16, 17). The results show, in theory, that teacher readiness and student competency development are interdependent. Practically speaking, they suggest that curriculum designers and legislators should prioritise flexible, context-appropriate modules that incorporate both competencies. In contrast to studies from Rwanda and Vietnam that found difficulties incorporating environmental education into the curriculum, this study closes a significant gap in the literature by offering empirical data from Indonesia (20, 21). The distinct environmental context of Indonesia may also be reflected in the uneven development of competencies. In contrast to Peru, Colombia, or China—contexts where high correlations between environmental knowledge and pro-environmental behaviour have been documented—students in this study face ecological challenges such as deforestation and urban waste management (19).

The Discussion elucidates the reasons for the variability in abilities within the Indonesian primary school context. The data show that high scores in basic environmental behaviors are due to regular school activities such as cleanliness rules, energy-saving habits, Adiwiyata/P5 activities and teacher-parent reinforcement. On the other hand, low scores in graphing and data visualization skills are linked to poor module design, uneven teacher preparation and a lack of media in the classroom. These patterns indicate a developmental disparity between habit formation and advanced scientific representation, which enhances conceptual understanding, contextualizes findings within Indonesia's educational context and elucidates the consequences for module development practices.

Conclusion

The purpose of this study was to investigate how instructors and students in Indonesian primary schools view and use scientific communication and environmental literacy. The results address the research topics amply. Although they claim a lack of thorough instructional modules, teachers usually acknowledge the significance of both competencies. Although students still lack more sophisticated skills, especially in data visualisation, they demonstrate a strong commitment to fundamental environmental principles and to effective communication. The idea that teacher ability greatly influences student results is supported by the strong connections between teachers' and students' competences, particularly the large relationship between instructors' environmental literacy and students' equivalent skills. Nonetheless, the lack of association between teachers' scientific communication and environmental literacy points to a structural deficiency in teacher preparation.

These results have significant ramifications. The study demonstrates that scientific communication and environmental literacy are mutually reinforcing skills that require integrated instructional support, as evidenced by empirical evidence from an underrepresented area. Practically speaking, the findings underscore the crucial need for experimentally validated, context-responsive modules that bridge ecological knowledge with effective communication skills. These courses can enhance students' capacity for both sustainable behaviour and clear communication of environmental issues, both of which are crucial components of 21st-century citizenship.

The study has limitations despite its contributions. Although insightful, the qualitative Sample may not accurately reflect geographical diversity and self-reported data may introduce social desirability bias. Additionally, the cross-sectional design makes it more difficult to evaluate long-term improvements in competency. To determine causal effects, future research should employ comprehensive designs that monitor changes over time, compare studies across nations or regions and test specific teaching modules experimentally. This type of effort will enhance knowledge on how to systematically improve scientific communication and environmental literacy across various educational contexts.

Abbreviations

CVI: Content Validity Index, EL: Environmental Literacy, GEL: Teachers' Environmental Literacy, GMR: Module Requirement, GSC: Teachers' Scientific Communication, KMO: Kaiser-Meyer-Olkin measure, P5: Fifth Grade Projects, SC: Scientific Communication, SD: Standard Deviation, SEL: Students' Environmental Literacy, SSC: Students' Scientific Communication.

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Author Contributions

Ismail Marzuki: Conceptualization, Analysis, Model Preparation, Rusijono: Data Collection, Organi-Zation, Data Testing, Wahono Widodo: Data Gathering, Data Analysis, Suryanti: Data Testing, Data Analysis, Binar K. Prahani: Data Testing, Data Validation.

Conflict of Interest

The authors assert that there are no conflicts of interest. The study's results, analysis and conclusions were not affected by any financial, personal, or professional ties.

Data Availability

The datasets generated and analyzed during this study are available from the corresponding author upon reasonable request. Survey responses, interview transcripts and quantitative results supporting the findings are stored securely and can be shared for academic purposes while respecting participant confidentiality and institutional ethical standards.

Declaration of Artificial Intelligence (AI) Assistance

While writing the manuscript, the authors used AI-assisted tools to check their grammar and vocabulary. The authors created all of the important stuff.

Ethics Approval

The research conducted followed ethical guidelines and principles as evidenced through obtaining written approval from the school authority, having each participant sign an informed consent prior to conducting the interview; ensuring that all data collected would be kept confidential.

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