



Socio-Scientific Issues (SSI)-Based E-Module on Indragiri River Pollution and Land Conversion: A Needs Analysis from the Perspective of Biology Teachers at Senior High School

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Abstract

The low levels of environmental literacy and decision-making skills among senior high school students remain a pressing concern, particularly in regions facing real ecological challenges such as Keritang District, Indragiri Hilir Regency. This study aimed to: (1) describe the current condition of teaching materials used in Biology learning; (2) examine teachers' perspectives on students' environmental literacy and decision-making skills; (3) explore the relevance of local issues as socio-scientific issue (SSI) contexts; and (4) identify teachers' needs regarding the characteristics of an SSI-based e-module. A qualitative approach with a single case study embedded units design was employed, involving three Biology teachers from all active senior high schools (SMA/MA) in Keritang District, selected through total sampling. Data were collected through semi-structured interviews and lesson plan documentation, analyzed using the interactive model of Miles, Huberman, and Saldaña, and validated through source triangulation and member checking. The findings reveal that: (1) the teaching materials currently used do not incorporate local contexts from Keritang District, as indicated by lesson plans that lack integration of area-specific environmental issues; (2) from teachers' perspectives, students' environmental literacy remains at the awareness level, while their decision-making skills are still limited; (3) the issues such as pollution of the Indragiri River and land conversion are highly relevant as local SSI contexts due to their rich scientific, social, economic, and ethical dimensions; and (4) there are differences in implementation readiness across schools: public high schools are more prepared to use digital e-modules, while private madrasah require printed modules due to limited access to digital devices. Nevertheless, both require teaching materials that include authentic local data, higher-order thinking (HOTS) activities, e-modules accessible offline via smartphones and printable as an alternative, as well as alignment with the curriculum. These findings represent a needs analysis as the first phase in the development of an e-module, with the design and validation stages planned as subsequent phases. The results of this needs analysis provide an empirical basis for designing a locally grounded SSI-based e-module to improve the quality of Biology learning in Keritang district.

Keywords: Decision-making skills; Environmental literacy; Indragiri River pollution; Local socio-scientific issues; SSI-based e-module

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INTRODUCTION

The environmental crisis occurring across various parts of the world increasingly threatens ecosystem sustainability and the quality of human life (Martin-Ortega et al., 2022). In Indonesia, pressure on natural resources continues to intensify, as reflected in the annual loss of forest cover averaging 650,000 hectares (Kraus et al., 2021) along with widespread water pollution, land degradation, and declining biodiversity (Faizi et al., 2024). Riau Province, known for its ecologically significant tropical forest areas, is not exempt from these pressures.

Data indicate that forest cover in Riau Province declined from 1,489,410 ha in 2017 to 1,398,582 ha in 2022, with an accumulated deforestation of 28,781 ha during that period (Fitria, 2022). These forest areas play a strategic role in maintaining regional ecosystem balance and biodiversity (Dharmawan et al., 2024).

Similar conditions are observed in Indragiri Hilir Regency. According to data from the Regional Environmental and Sanitation Agency (DLHK), water pollution is the most dominant type of environmental contamination, affecting 248 villages and sub-districts (DLHK Kabupaten Indragiri Hilir, 2022). In Keritang District specifically, this issue is reflected in land-use conversion in forest areas, the discharge of pesticides into the Indragiri River, and suboptimal household waste management (DLHK Kabupaten Indragiri Hilir, 2022; Apriliani et al., 2024). If these conditions persist, the impacts will extend beyond environmental degradation to include biodiversity loss, increased risks of global warming, and economic losses for local communities (Auffret & Svenning, 2022; Khachoo et al., 2024).

Such complex environmental problems are fundamentally linked to the level of environmental literacy among society, particularly younger generations (Mustofa & Sueb, 2025). Environmental literacy is understood as the capacity to comprehend environmental conditions, interpret occurring problems, and take appropriate action to maintain and improve environmental quality (Tomas et al., 2022). In operationalizing the concept of environmental literacy, this study refers to the framework proposed by Disinger & Roth (1992), which categorizes environmental literacy into three hierarchical levels. First, *nominal environmental literacy*, referring to a condition in which individuals recognize environmental terms and issues at a surface level but are not yet able to explain cause-effect relationships scientifically. Second, *functional environmental literacy*, defined as the ability to understand and systematically explain the relationships between environmental phenomena, their causes, and their impacts. Third, *operational environmental literacy*, representing the highest level, in which individuals are able to critically evaluate environmental problems, consider multiple perspectives, and take responsible actions based on scientific evidence. This framework also identifies four key components of environmental literacy that are mutually reinforcing, namely knowledge, attitudes, skills, and behavior (Disinger & Roth, 1992).

This study specifically focuses on three components: knowledge, attitudes, and skills as observable aspects through teachers' perspectives and as components that can be developed through SSI-based teaching materials. However, research findings indicate that students' environmental literacy remains relatively low: 38.9% of students fall into the low category, 54.4% into the moderate category, and only 6.7% into the high category (Fahlevi et al., 2023). This condition is influenced by various factors, including limited knowledge and training for educators (Petkou & Andrea, 2021), suboptimal integration of environmental education in the curriculum (He, 2025; Orbanic & Kovač, 2021) and insufficient student engagement in outdoor learning activities (Sasa et al., 2022).

Low environmental literacy cannot be separated from weak decision-making skills among students when confronted with complex and multidimensional environmental problems (Agustira et al., 2025). Decision-making competence encompasses the ability to evaluate information from multiple sources, consider alternative solutions based on scientific evidence and relevant values, and determine responsible actions (OECD, 2023; Putri et al., 2025). These two competencies are mutually reinforcing: environmental literacy provides the foundation of knowledge and awareness, while decision-making skills propel students toward concrete, science-based action (Hokayem & Jin, 2019). Unfortunately, research by Triyanti et al. (2025) indicates that 52.3% of senior high school students demonstrate low decision-making skills, 13.5% moderate, and only 34.2% high- figures suggesting that science learning has historically prioritized conceptual mastery over reasoning in the face of open-ended problems.

The urgency of developing these two competencies aligns with the Programme for International Student Assessment (PISA) 2025 framework, which introduces the concept of

Agency in the Anthropocene - the capacity of young people to combine scientific knowledge, values, and ethical considerations in responding to socio-ecological crises (OECD, 2023). Similarly, the Merdeka Curriculum emphasizes contextual learning, critical thinking, and real-world problem-solving as core competencies for senior high school graduates (Fatmawati et al., 2024). Both policy frameworks implicitly demand teaching materials capable of bringing real environmental issues into the learning space, rather than presenting concepts in an abstract manner (Kurniawan et al., 2024).

One approach that has been both theoretically and empirically proven relevant to address this need is the Socio-Scientific Issues (SSI) approach. SSI is defined as science-based issues that are open-ended, controversial, and closely related to social, economic, ethical, and environmental dimensions (Zeidler et al., 2005). This approach integrates real-world problems into science learning to foster critical thinking, decision-making, and scientific literacy among students (Dusturi et al., 2024; Ke et al., 2021). Students are not only asked to understand scientific facts but are also expected to consider diverse social perspectives, construct scientific arguments, and reflect on the ethical implications of each decision (Sari et al., 2025).

Numerous studies have demonstrated that SSI-based learning effectively improves environmental literacy (Viehmann et al., 2024) decision-making skills (Magtibay & Nueva España, 2023). In the context of this research, the issues of Indragiri River pollution and land conversion in Keritang District hold considerable potential as authentic local SSI contexts: both issues are open-ended, involve scientific, economic, and ethical dimensions, and are closely connected to students' daily lives, thereby potentially increasing motivation and cognitive engagement (Herman et al., 2021). Nevertheless, the implementation of SSI in school science learning continues to face a primary challenge in the limited availability of teaching materials that explicitly and systematically integrate local issues into structured learning activities (Chen & Xiao, 2021; Badeo et al., 2024; Magtibay & Nueva España, 2023).

E-modules represent the most appropriate solution for bridging the SSI approach with practical learning needs in the field. Unlike static printed student worksheets or one-directional instructional videos, an e-module is a digital teaching material that enables the integration of text, images, videos, authentic data, and independent learning activities within a single platform accessible via digital devices (Listanto et al., 2025; Delita et al., 2022). These characteristics make e-modules highly compatible with the requirements of local SSI-based learning: Indragiri River water quality data can be presented visually and interactively, decision-making scenarios can be designed based on real evidence, and students can access content flexibly without depending on the teacher's presence. However, the development of e-modules specifically containing local socio-scientific issues and oriented toward improving students' environmental literacy and decision-making skills remains very limited (Viehmann et al., 2024; Dewi et al., 2025).

To date, no SSI-based e-module exists that specifically uses the issues of Indragiri River pollution and riparian land conversion as an authentic context for Biology learning at the senior high school level in Keritang District. Studies combining the perspectives of local Biology teachers with an analysis of local issue relevance and e-module characteristic needs are also extremely limited. Yet, Biology teachers are the parties who best understand the characteristics of their students, the actual learning conditions, and the teaching material needs of their schools. Teachers' perspectives therefore constitute an empirical foundation that cannot be overlooked in the process of developing contextual and implementable teaching materials (Sartika et al., 2024). In the development of teaching materials, needs analysis is a crucial stage to ensure that the designed product genuinely addresses real problems in the field, rather than being a merely speculative innovation (Putri & Asrizal, 2023).

Based on the foregoing, this study aims to: (1) describe the condition of Biology teaching materials used in SMA/MA schools in Keritang District; (2) identify teachers' perspectives on students' environmental literacy and decision-making skills; (3) explore teachers' perspectives

on the relevance of Indragiri River pollution and land conversion as local SSI contexts; and (4) analyze teachers' needs regarding the characteristics of an SSI-based local e-module for senior high school Biology learning.

METHOD

Research Approach and Design

This study employed a qualitative approach with a single case study design with embedded units of analysis. The qualitative approach was selected because the research aims to explore in depth the perspectives, experiences, and needs of Biology teachers regarding the development of a local SSI-based e-module in the context of Keritang District. This approach enables a more comprehensive understanding of the learning phenomenon in its real-world setting, beyond numerical measurement.

The single case study design with embedded units of analysis follows the framework of Yin (2018), in which a single case—the condition of Biology learning and teaching material needs in Keritang District—is examined through multiple units of analysis, namely individual Biology teachers from all SMA/MA schools in the area. This design enables an in-depth understanding of the phenomenon within its real-life context, while also allowing the exploration of variations in teachers' perspectives across units of analysis to enrich the findings (Merriam & Tisdell, 2016; Yin, 2018). Furthermore, this design is appropriate given the complexity of the educational setting, including differences in school conditions, teacher characteristics, and local environmental contexts.

Research Site and Participants

This study was conducted in SMA/MA schools in Keritang District, Indragiri Hilir Regency, Riau Province. Keritang District is served by two active senior secondary education institutions (SMA/MA), consisting of one public high school and one private madrasah. Digital infrastructure in this area remains limited, with unstable internet connectivity across much of the district, making access to online learning consistently unreliable. Although the two institutions differ in terms of governance (public and private), both face similar challenges in the availability of contextual teaching materials and digital infrastructure. The site was selected based on two considerations: (1) the presence of local environmental issues—namely Indragiri River pollution and riparian land conversion—which are relevant as socio-scientific issue (SSI) contexts in Biology learning; and (2) the absence of teaching materials integrating local SSI in this context.

Participants were selected using a total sampling approach, given the limited number of eligible Biology teachers in the research area. The inclusion criteria were: (1) active Biology teachers at the SMA/MA level; (2) a minimum of three years of teaching experience; (3) currently teaching in the research area; and (4) willingness to participate voluntarily.

Based on these criteria, all eligible teachers were included, resulting in a total of three participants (G1, G2, G3) from two institutions: one public senior high school (SMA) and one private Islamic senior high school (MA). This number represents the entire population of active Biology teachers at the SMA/MA level in the study area. All participants hold a bachelor's degree (S1) in Biology Education and have between 13 and 15 years of teaching experience.

Research Instruments and Data Collection

Data were collected through semi-structured interviews and document analysis. In this study, the researcher acted as the primary instrument, supported by a semi-structured interview guide that was validated through expert judgment by two specialists in science education.

Interviews were conducted face-to-face with each participant for approximately 60–90 minutes and were audio-recorded with participants' consent to enable verbatim transcription. The interview guide encompassed twelve aspects aligned with the research objectives, including teacher profiles, instructional strategies, the condition of teaching materials, learning constraints, evaluation practices, and teachers' perceptions of students' environmental literacy

and decision-making skills. It also explored the relevance of Indragiri River pollution and land conversion as local socio-scientific issue (SSI) contexts, teachers' digital readiness, challenges in environmental-based learning, and their needs regarding the development of an SSI-based e-module. The distinction between learning constraints and learning problems was explicitly defined based on their respective focus—technical-operational versus conceptual-pedagogical aspects.

Document analysis was conducted on lesson plans (RPP) obtained from participants as supplementary data to support and verify interview findings. Although the available documents were not entirely complete, this limitation itself represents a meaningful finding, as it reflects the limited availability and utilization of instructional materials in the field.

Based on the results of interviews and document analysis, an instrument grid for teacher needs analysis was developed, encompassing 12 aspects. This grid served as a reference for identifying teachers' needs in module development and the availability of lesson plans (RPP), as presented in Tables 1 and 2.

Table 1. Interview Instrument Grid for Teacher Needs Analysis (12 Aspects)

No	Aspect/Domain	Sample Questions	Research Purpose
1	Teacher Profile and Background	Could you please describe your highest educational background? How long have you been teaching Biology? Which grade(s) are you currently teaching?	To describe participant characteristics
2	Instructional Materials/Planning Documents	Who usually develops the instructional materials you use? Are they prepared through the MGMP, independently, or provided by publishers?	To identify the condition of instructional materials
3	Teaching Approaches and Strategies	What learning approaches are commonly used when teaching environmental topics? What models or methods are typically applied in environmental change topics?	To identify the teaching strategies implemented
4	Textbooks/Learning Materials Used	What learning resources do you use? Do the existing materials incorporate local environmental issues? What types of materials are needed?	To identify the condition and needs of learning materials
5	Teaching and Learning Activities and Student Difficulties	Do students often experience difficulties in learning environmental topics? What are the causes of these difficulties? What is the allocated instructional time?	To identify barriers in the teaching and learning process
6	Learning Evaluation	What aspects are assessed in the evaluation? Which cognitive levels (C1–C6) are typically measured?	To identify evaluation practices
7	Environmental Literacy	Are you familiar with the concept of environmental literacy? How would you describe students' current level of environmental literacy?	To identify students' environmental literacy based on teachers' perceptions
8	Decision-Making Skills	Are you familiar with the concept of decision-making in learning? How would you describe students' current decision-making skills?	To identify students' decision-making skills based on teachers' perceptions
9	Local Socioscientific Issues	Are you aware of environmental issues in Indragiri Hilir, such as pollution in the Indragiri River and land-use	To assess the relevance of local issues as SSI contexts

No	Aspect/Domain	Sample Questions	Research Purpose
10	Modules and Implementation Readiness	change? Have these issues been integrated into teaching? Are you familiar with instructional modules? Are you ready to use modules based on local SSI for environmental topics and conservation?	To identify teachers' readiness to use modules
11	Challenges in Teaching	Please describe the challenges faced in Biology teaching from the perspectives of teachers, students, and facilities/infrastructure.	To identify barriers to instructional implementation
12	Expectations and Suggestions for the Module	What are your expectations for the local SSI-based module to be developed? What features, content, or design do you expect the most?	To explore teachers' expectations as a basis for module design

Table 2. List of Documents Analyzed per Participant (3 Teachers, 2 Schools)

No	Code	School	Document Type	Title/Topic	Completeness	Local Issue	SSI Elements
1	G1	Public Senior High School	Textbook (review)	Environmental Change — Ministry of Education textbook (Grade X)	Available	None**	None
2	G2	Public Senior High School	Textbook (review)	Environmental Change — Ministry of Education textbook (Grade X)	Available	None**	None
3	G3	Private Islamic Senior High School (MA)	Lesson Plan / Teaching Module	Chapter 11: Environmental Change (Grade X)	Complete	None*	None

Notes:

*) The teaching module (Chapter 11) includes general environmental issue contexts but does not integrate specific local issues from Keritang District.

**) G1 and G2 did not provide lesson plans because the Environmental Change topic had not yet been taught at the time of data collection; therefore, the analysis was conducted on the Ministry of Education textbook, which is national in scope and does not incorporate local issue contexts.

Data Analysis

Data were analyzed using the interactive analysis model of Miles et al. (2014), comprising three simultaneous stages: data reduction, data display, and conclusion drawing/verification.

First, data reduction involved verbatim transcription of interview data, followed by repeated readings to identify meaningful units. The analysis continued with open coding to label these units, followed by axial coding to organize codes into categories and subsequently develop overarching themes aligned with the research objectives. For example, a teacher's statement such as "*I have never used teaching materials that address the Indragiri River issue*" was coded as *absence of local SSI-based teaching materials*, categorized under *condition of*

teaching materials, and further developed into the theme *the need for local-context SSI-based e-module development*.

Second, data display was conducted through descriptive narratives, cross-case thematic matrices, and summary tables to facilitate pattern identification and the exploration of variations in perspectives across participants. Third, conclusion drawing and verification were carried out iteratively throughout the analysis process through continuous reflection and analytic memo writing. To ensure the credibility of the findings, method triangulation was applied by comparing data obtained from interviews and document analysis.

Data Validity

Data validity was ensured through two strategies. First, source triangulation was employed by comparing and cross-checking data obtained from the three participants (G1, G2, and G3) and lesson plan (RPP) documents to verify the consistency of information across data sources. Second, member checking was conducted by returning a written summary of the preliminary findings to each participant through face-to-face meetings lasting approximately 30 minutes. Participants were asked to confirm whether the researcher's interpretations accurately reflected their perspectives. All participants confirmed that the findings appropriately represented their views, with no substantial corrections to the content, thereby supporting the credibility and accuracy of the study findings.

This study was conducted in accordance with established research ethics principles. Research approval was formally obtained from the researcher's institution prior to data collection. In addition, permission to conduct the study was granted by the principals of each participating school. All participants were informed about the research objectives, data collection procedures, and their right to withdraw at any time without any consequences. Informed consent was obtained prior to the interviews, including consent for audio recording. Participant confidentiality was maintained through the use of participant codes (G1, G2, and G3) in all research reports, and audio recordings were accessible only to the research team.

RESULTS AND DISCUSSION

All preliminary findings were confirmed with each participant through member checking and were found to accurately reflect their intended meanings.

Participant Profile

The study participants consisted of three Biology teachers from senior high schools (SMA/MA) in Keritang District, with teaching experience ranging from 13 to 15 years and educational backgrounds in Biology Education at the undergraduate (Bachelor's) and graduate (Master's) levels. All participants actively taught grades X to XII and were drawn from two schools, representing all active SMA/MA institutions in Keritang District, namely one public senior high school (G1 and G2) and one private Islamic senior high school (G3). These two schools exhibit different infrastructural characteristics. The public school is relatively more open to the use of digital tools in instruction, whereas the private Islamic school enforces restrictions on mobile phone use during class hours. This difference has implications for the types of instructional materials that are most feasible to implement in each school context. A detailed profile of the participants is presented in Table 1.

Table 3. Research Participant Profile

Code	School	Teaching Experience	Last Education	Classes Taught	Initial SSI Knowledge
G1	Public SMA X	13 years	B.Ed. Biology	X–XI	Not familiar
G2	Public SMA X	13 years	B.Ed. Biology	X–XII	Not familiar
G3	Private MA Y	15 years	B.Ed. Biology	X–XII	Limited familiarity

A notable initial finding was the variation in familiarity with socio-scientific issues (SSI) among the participants. G1 and G2 reported that they had never encountered the concept of

SSI, whereas G3 indicated some familiarity with the term, although it had not been systematically implemented in teaching practice. This variation may be influenced by differences in individual exposure to professional development, access to information, or participation in academic or training activities related to innovative pedagogical approaches. This finding suggests that extensive teaching experience does not necessarily translate into familiarity with pedagogical innovations such as SSI. Therefore, professional support in the form of targeted training and the provision of practical teaching materials remains essential (Widad et al., 2025).

Condition of Teaching Materials and Learning Tools

Based on the results of interviews and analysis of lesson plan (RPP) documents, all participants reported that the primary teaching materials used in Biology instruction are still dominated by national textbooks, student worksheets (LKPD), and supplementary resources from the internet. Instructional planning documents are generally developed through the MGMP forum and subsequently adapted to meet the specific needs of each school. The analysis of the RPP documents obtained from participants indicates that lesson plans include several general environmental issues, such as pollution and environmental change; however, none explicitly incorporate specific local issues from Keritang District, such as pollution of the Indragiri River or land-use conversion along riverbanks, as authentic learning contexts. This condition confirms and reinforces the participants' statements that the available teaching materials do not adequately and systematically incorporate local environmental issues. One teacher explained:

"The existing textbooks are good for explaining biological concepts, but most of the examples are drawn from outside the local area. Students find it difficult to relate to the material being learned." (G1)

The gap between teaching material content and students' real-life context is not merely a technical issue; it has direct implications for the meaningfulness of learning. Instruction that does not connect content to students' real-life experiences tends to result in lower learning motivation and less in-depth conceptual understanding (Wei et al., 2025). Therefore, a contextual learning approach is needed to bridge subject matter with students' lived realities. This finding is consistent with Nida et al. (2020), who reported that the lack of contextual teaching materials is a major barrier to the implementation of socio-scientific issues (SSI)-based learning in schools. In the context of Keritang District, this further underscores the urgency of developing an e-module that explicitly integrates issues such as pollution of the Indragiri River and land-use conversion as authentic contexts in Biology learning.

Students' Environmental Literacy: Teachers' Perspectives

All participants perceived that students' environmental literacy remains at a basic awareness level and has not yet reached functional environmental literacy, which requires the ability to explain cause–effect relationships, evaluate issues scientifically, and make responsible decisions. However, there were nuanced differences in perspectives among the three teachers. G1 and G2 considered students' environmental literacy to be relatively low, primarily attributing this to the lack of contextual teaching materials. In contrast, G3 expressed a slightly more optimistic view, noting that some students have shown concern for local environmental issues, although they are not yet able to analyze them scientifically. One teacher stated:

"Students know that a polluted river is not good, but when asked why it happens, what the impacts are, and what the solutions might be, they still struggle to respond." (G2)

Similarly, G1 observed that students tend to be less responsive when addressing environmental questions: *“Students nowadays are more passive.”* (G1). This is reinforced by G3’s statement that environmental literacy and decision-making have not been explicitly taught in instruction: *“Environmental literacy and decision-making in environmental change topics have not yet been explicitly trained.”* (G3). According to Disinger & Roth (1992), this condition indicates that students are still at the nominal level of environmental literacy, meaning they can recognize environmental issues at a surface level but are not yet able to analyze cause–effect relationships scientifically.

These differing perspectives may reflect variations in school contexts; students in the private Islamic school where G3 teaches may have different levels of engagement with local environmental issues compared to those in the public school. Despite these differences, all teachers agreed that students have not yet progressed beyond the awareness stage toward higher levels of environmental literacy. This finding is consistent with Fahlevi et al. (2023) who reported that most senior high school students fall within the low to moderate categories of environmental literacy.

Teachers identified several contributing factors, including the lack of contextual teaching materials, limited field-based learning activities, and evaluation practices that are still dominated by lower-order cognitive skills (C1–C3). These findings imply that the e-module to be developed should incorporate activities that progressively build environmental literacy, starting from the introduction of local facts, followed by cause–effect analysis, and culminating in the evaluation of solutions based on scientific evidence.

Students' Decision-Making Skills: Teachers' Perspectives

All participants assessed that students' decision-making skills are still low. Students are not yet accustomed to systematically analyzing problems, comparing multiple alternative solutions, considering the consequences of each option, and arriving at decisions based on scientific evidence. One teacher stated:

“When given an environmental problem, students often respond immediately without a clear rationale. They are not yet accustomed to weighing multiple options.” (G3)

Notably, G3, who was more familiar with SSI, provided a deeper analysis of the root cause. G3 assessed that students' low decision-making skills are not merely a student-level weakness but rather a reflection of a learning design that has not historically provided students with opportunities to practice engaging with open-ended problems. G1 and G2 tended to attribute this condition to low learning motivation and limited instructional time. This difference in perspective suggests that teachers with a broader pedagogical understanding tend to view learning problems in a more structural and systemic manner.

Overall, these findings indicate that Biology learning has historically emphasized right-or-wrong answers rather than the reasoning process involved in tackling open-ended problems. However, real-world environmental issues—such as Indragiri River pollution—do not have a single correct solution and require consideration of scientific, economic, social, and ethical dimensions. This aligns with Triyanti et al. (2025), who found that more than half of senior high school students demonstrate low decision-making skills. Therefore, the SSI-based e-module to be developed should incorporate authentic, local data-driven decision-making scenarios that encourage students to evaluate multiple perspectives before arriving at well-reasoned conclusions.

Relevance of Local SSI in Keritang District

All teachers agreed that the issues of Indragiri River pollution and riparian land conversion are highly relevant as a context for SSI-based Biology learning. The proximity of these issues to students’ daily lives was considered a key factor in enhancing motivation and cognitive engagement. One teacher stated:

"When discussing a river in our own area, students are immediately interested because they see its condition every day." (G1)

Although all participants acknowledged this relevance, they expressed differing levels of readiness to integrate such issues into instruction. G1 and G2 reported that they had never systematically incorporated local issues, citing the lack of structured teaching materials and concerns about maintaining alignment with learning objectives. G3 indicated having informally introduced local environmental issues in classroom discussions but noted the absence of clear pedagogical guidance for integrating them into structured learning activities. These findings suggest that the primary barrier lies not in the relevance of local issues, but in the limited availability of instructional tools capable of translating them into structured and measurable learning experiences—a gap that can be effectively addressed through an SSI-based e-module (Chen & Xiao, 2021).

Based on interview results, both local issues possess rich and complementary SSI dimensions. Indragiri River pollution encompasses scientific aspects (aquatic ecosystems and contamination), social aspects (community dependence), economic impacts (fisheries and agriculture), and ethical considerations (intergenerational responsibility). Riparian land conversion involves biodiversity and conservation concerns, as well as trade-offs between economic development and ecological sustainability. The proximity of context to students' lives has been shown to enhance cognitive engagement and the quality of scientific discussion (Songer & Ibarrola Recalde, 2021; Tsai, 2018). The relationship between both local issues, related Biology topics and targeted competencies is summarized in Table 2.

Table 4. Potential of Local Issues as SSI Contexts in Biology Learning

Local Issue	Related Biology Topics	SSI Dimensions	Competencies Developed
Indragiri River Pollution	Ecosystem, Environmental Pollution	Scientific, Social, Economic, Ethical	Environmental literacy, solution analysis, decision-making
Riparian Land Conversion	Biodiversity, Conservation	Scientific, Social, Economic, Ethical	Trade-off analysis, scientific argumentation, sustainability-oriented decision-making

Teachers' Expectations Regarding the SSI-Based E-Module

An in-depth exploration of teachers' needs revealed four interrelated categories of expectations. First, authentic local content: teachers expected the e-module to incorporate real environmental data from Keritang District, including field documentation photographs, videos of the Indragiri River, and measurable water quality data. Such authentic visual media have been shown to enhance student motivation and engagement in real-world learning contexts (Atalaya et al., 2023). One teacher stated:

"Real river data, photos of its condition — those will make students more serious about discussing it because they know it is actually happening here." (G1)

Second, HOTS-based pedagogical design: activities within the e-module should facilitate analysis, evaluation, and decision-making rather than merely presenting concepts. This aligns with the view that effective SSI-based learning promotes scientific argumentation, ethical reflection, and evidence-based decision-making (Alred & Dauer, 2024; Zhang & Hsu, 2025). One teacher noted:

"The ideal e-module is one that makes students not only understand the biology concepts but also think: what should we do about our river problem?" (G2)

Third, digital accessibility: the e-module should be accessible via Android smartphones, support offline use, and feature an intuitive interface. This requirement is particularly important given the uneven internet connectivity in Keritang District. One participant stated:

"The signal here is not always stable, so if the e-module requires a constant internet connection, students won't be able to use it at home." (G3)

Fourth, curriculum alignment: the e-module must be synchronized with the Biology Learning Outcomes for the topic of Environment and Its Conservation, so that it can be integrated into daily instruction without sacrificing the attainment of required competencies. This expectation reflects teachers' practical concern that instructional innovations are often difficult to implement because they are misaligned with current curriculum demands.

Collectively, these expectations indicate a strong need for teaching materials that reflect the principles of SSI-based learning and support the development of *Agency in the Anthropocene*, as emphasized in the PISA 2025 framework (OECD, 2023). A summary of teachers' needs across the twelve aspects is presented in Table 3.

Table 5. Summary of Teacher Needs Across 12 Study Aspects

No	Aspect	Current Condition	Needs / Expectations
1	Teaching Materials	General textbooks, lacking local context	E-module containing local environmental issues of Keritang District
2	Teaching Approach	Scientific approach, constrained by limited media	Problem-based approach with local SSI context
3	Student Difficulties	Abstract content, irrelevant to real life	Real context close to students' direct experience
4	Assessment	Dominated by C1–C3, minimal HOTS instruments	Assessment instruments measuring C4–C6 competencies
5	Environmental Literacy	Students at awareness stage	Activities that progressively build environmental literacy
6	Decision-Making	Low; inadequate teaching tools	Decision-making scenarios based on local data and scientific evidence
7	Local SSI Issues	Not yet integrated; no structured materials	E-module containing river pollution and land conversion issues
8	E-Module Readiness	Familiar, not accustomed to using	User-friendly e-module on smartphones, offline-friendly
9	Content	No Keritang-specific local content	Real data (photos, videos, Indragiri River water quality data)
10	Pedagogy	Lectures and conventional discussion	Discussion, scientific debate, analysis, decision-making
11	Accessibility	Reliance on printed books	Compatible with Android smartphones, accessible without internet
12	Curriculum	No SSI integration in lesson plans	Aligned with Biology Learning Outcomes on Environment and Conservation

Discussion

The four main findings of this study form a coherent and mutually reinforcing picture of the need to develop a local socio-scientific issues (SSI)-based e-module in Keritang District, with important theoretical and practical implications that warrant further discussion. The lack of contextualized teaching materials directly contributes to the low levels of students' environmental literacy and decision-making skills. Without instructional materials that incorporate real-world issues, students have limited opportunities to practice analyzing environmental problems in a scientific and multidimensional manner. This finding is consistent with Giamellaro et al. (2025), who reported that students' cognitive engagement increases significantly when science learning is connected to real-life contexts.

On the other hand, the high relevance of issues such as pollution in the Indragiri River and land-use conversion as local SSI contexts provides a strong foundation for the development of authentic and meaningful e-modules. This finding aligns with Viehmann et al. (2024), who identified environmental issues as the most dominant SSI topics in global science education research, highlighting their relevance and significance as learning contexts. More specifically in the Indonesian context, Matthiesen et al. (2024) demonstrated that locally grounded issues such as land-use change are perceived as spatially and socially relevant by students, thereby strengthening their role as authentic SSI contexts for instructional material development. This is further supported by Kirana et al. (2022), who found that SSI-based science learning in the context of local environmental pollution significantly improves junior high school students' scientific literacy. These findings indicate that the two issues identified in Keritang District are not only thematically relevant but also empirically effective as foundations for SSI-based learning.

The differing perspectives between G3, who is more familiar with SSI, and G1–G2, who are less familiar, indicate that teachers' needs extend beyond instructional materials to include pedagogical knowledge. This implies that the e-module to be developed should be accompanied by implementation guidelines that enable teachers—including those who are not yet familiar with SSI—to use it effectively in the classroom. This is consistent with Kinskey & Zeidler (2024), who emphasize that teachers unfamiliar with SSI tend to be reluctant to implement it due to a lack of confidence in both content knowledge and pedagogical approaches. Similarly, Zhang & Hsu (2025) identified the lack of SSI-specific instructional resources as a major practical barrier faced by teachers. Therefore, the e-module should integrate clear pedagogical guidance that accommodates teachers' needs and perspectives, as also suggested by Dayan & Tsybulsky (2025), who argue that effective SSI instructional materials must incorporate teacher-oriented pedagogical support.

Overall, teachers' needs can be mapped into four interrelated components: (1) the relevance of local context as a foundation for student motivation and engagement; (2) higher-order thinking skills (HOTS)-oriented instructional design as a mechanism for developing environmental literacy and decision-making skills; (3) technological accessibility as a prerequisite for practical implementation; and (4) curriculum alignment as a guarantee of sustainability. It should be noted that, although alternative approaches such as SSI-based printed materials or community-based projects could theoretically address some of these needs, all three teachers consistently emphasized the need for media that incorporate authentic visual data, are accessible for independent student use, and function in offline settings. These characteristics are optimally fulfilled by digital e-modules, particularly in the public senior high school context where infrastructure is more supportive. However, the findings also reveal that the private Islamic school requires additional flexibility, particularly the ability to print materials.

Therefore, the proposed e-module should be designed as a single product with dual-mode access: offline-accessible via smartphones and printable as a PDF without losing its SSI-based instructional substance. This single-product, dual-mode approach is more feasible from a development perspective and ensures that all students in Keritang District, regardless of differences in school infrastructure, can benefit from local SSI-based learning. These four components serve as the primary foundation for the design of the proposed e-module. The conceptual structure of the e-module, developed based on the needs analysis, is presented in Figure 1.

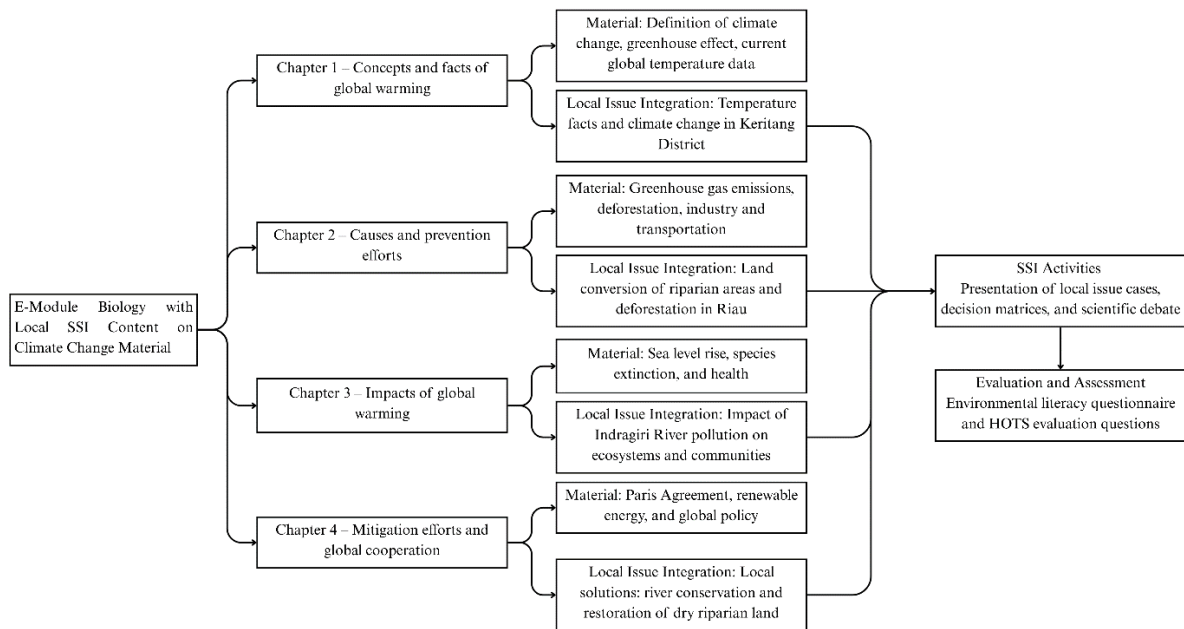


Figure 1. Conceptual Structure of the Biology E-Module Based on Local Socioscientific Issues (SSI) in Keritang District

As shown in Figure 1, the conceptual structure of the proposed e-module represents the findings of the needs analysis in a coherent instructional design. Each chapter connects general Biology concepts related to climate change with local socio-scientific issues in Keritang District, particularly Indragiri River pollution and land-use conversion. This structure is intended to help students move from conceptual understanding to contextual analysis, scientific argumentation, and evidence-based decision-making. The integration of local issue cases, decision matrices, scientific debate, and HOTS-oriented assessment further reflects the need to develop environmental literacy and decision-making skills through authentic learning experiences. Thus, the proposed e-module is not merely a digital version of existing teaching materials, but a locally grounded instructional framework that links scientific content, local environmental realities, and SSI-based pedagogy. However, as this study is limited to the needs analysis stage, the conceptual structure presented in Figure 1 still requires further development, expert validation, and empirical testing in classroom implementation.

CONCLUSION

This study indicates that Biology teaching materials in senior high schools (SMA/MA) in Keritang District have not yet integrated local contexts. As a result, students' environmental literacy remains at the awareness level, and their decision-making skills are not optimally developed. The issues of pollution in the Indragiri River and land-use conversion along riverbanks have been identified as relevant contexts for socio-scientific issues (SSI). However, this study has several limitations that should be considered when interpreting the findings. First, the study was conducted in a single district with only three teacher participants; therefore, the findings cannot be directly generalized to broader contexts. Second, the data on students' environmental literacy and decision-making skills were derived solely from teachers' perspectives, rather than from direct measurements of students. Third, the lesson plan (RPP) documents obtained were incomplete, limiting the scope of document analysis. These limitations should be taken into account in future research. Therefore, further studies should involve a larger sample, employ direct measurement instruments, and focus on developing, validating, and testing the effectiveness of locally based SSI modules across more diverse contexts.

RECOMMENDATION

Based on the findings, it is recommended that future research focus on developing and validating an SSI-based e-module that integrates local environmental issues of the Indragiri River, followed by testing its effectiveness in improving students' environmental literacy and higher-order thinking skills. Biology teachers are encouraged to incorporate local socio-scientific issues into learning activities to promote meaningful and contextual learning experiences. In addition, schools are expected to support the implementation of digital teaching materials by providing adequate facilities. These findings may also serve as a reference for curriculum developers in designing contextual and locally relevant Biology learning resources.

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AUTHOR CONTRIBUTIONS STATEMENT

Name of Author	C	M	So	Va	Fo	I	R	D	O	E	Vi	Su	P	Fu
Hasni	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	
Bambang Supriatno	✓	✓		✓				✓		✓	✓	✓		
Sariwulan Diana	✓	✓		✓			✓			✓	✓	✓		

CONFLICT OF INTEREST STATEMENT

Authors state no conflict of interest.

DATA AVAILABILITY

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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