

Developing Subject-Specific Pedagogy Using Socio-Scientific Issues on Forest and Peatland Fires for Scientific Argumentation and Environmental Ethics

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ABSTRACT

Science learning at the junior high school level is often dominated by teacher-centered approaches that emphasize conceptual mastery rather than contextual engagement. As a result, students' higher-order thinking skills, particularly scientific argumentation and environmental ethics, have not been optimally developed. Environmental issues such as forest and peatland fires require students to integrate scientific understanding with ethical and socially responsible decision-making. This study aimed to develop a valid Subject-Specific Pedagogy (SSP) based on the Socio-Scientific Issues (SSI) approach on the theme of forest and peatland fires to support the development of students' scientific argumentation skills and environmental ethics. The study employed a research and development design using the Borg and Gall model, limited to the expert validation and product revision stages. The developed products included a teaching module, student worksheets, handouts, a scientific argumentation skills test, and an environmental ethics questionnaire. Data were collected through expert validation sheets and analyzed using descriptive techniques. The results indicated that all SSP components met established validity criteria. Thus, the developed SSI-based SSP is considered valid and suitable for further empirical testing.

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1. INTRODUCTION

The demands of 21st-century education emphasize the development of learning and innovation skills, which include critical thinking and problem-solving skills, effective communication skills, collaborative skills, as well as creativity and innovation skills [1]. These skills are essential for preparing students to face an increasingly complex world, both in academic and professional contexts [2]. Within critical thinking skills, the construction and evaluation of rational arguments constitute a crucial aspect [3]. This ability requires a deep understanding of how to develop and evaluate scientific argumentation [4].

Argumentation skills are essential for students, as scientific argumentation represents the integration of two key 21st-century skills, namely critical thinking skills and communication skills [5]. Giri and Paily stated that students with strong scientific argumentation skills tend to demonstrate high levels of critical thinking [6]. Therefore, scientific argumentation also serves as a means of applying critical thinking, requiring students not only to understand scientific concepts but also to construct evidence-based arguments consisting of claims, supporting data, warrants, backings, and rebuttals [7].

The term *argumentation* in science education carries a different meaning from its use in everyday contexts. In science education, argumentation is not understood as an activity of attacking or discrediting opposing views, but rather as a logical and rational dialogical process used to examine the relationship between ideas and the evidence supporting them. The process of argumentation involves the development, evaluation, and validation of scientific knowledge, while also serving as a means of constructing scientific understanding. The essence of scientific argumentation lies in the formulation of statements or claims that are grounded in scientific evidence [8]. In science education, scientific argumentation is regarded as an essential practice that supports and strengthens students' scientific literacy [9]. Therefore, scientific argumentation skills need to be developed in science education to enhance students' scientific literacy [10].

One of the scientific argumentation models commonly used in science education is the Toulmin model, which consists of six main elements: a *claim*, referring to the statement or conclusion being proposed; *evidence*, which includes data or information supporting the claim; a *warrant*, which explains how the evidence supports the claim; *backing*, which functions as additional arguments or evidence that strengthen the warrant; a *rebuttal*, referring to exceptions or situations in which the claim does not apply; and a *qualifier*, which indicates the degree of certainty with which the claim can be asserted [11]. These indicators can be modified according to students' characteristics.

Based on the results of several studies that have examined the profiles of students' scientific argumentation skills in various regions, students' scientific argumentation skills in Indonesia are still considered to be low [5], [12]. In line with these findings, a study on plant biodiversity revealed that the scientific argumentation abilities of secondary school students in South Kalimantan were predominantly at Level 1, indicating that students were only able to formulate claims without supporting data or reasoning [13]. Furthermore, the role of teachers has not yet been optimal in eliciting students' argumentation skills, even though teachers are expected to facilitate learning processes that stimulate and support classroom argumentation.

In addition, science education is responsible not only for developing students' cognitive competencies but also for shaping their attitudes and values toward the environment. Therefore, environmental ethics is one of the essential competencies that needs to be fostered through science learning. Environmental ethics relates to students' ability to understand the relationship between humans and the environment, evaluate the impacts of human activities on nature, and make responsible decisions based on scientific and moral considerations. The development of environmental ethics in science education plays a crucial role in cultivating environmental awareness, caring attitudes, and responsibility for environmental sustainability.

In the learning context, environmental ethics cannot be optimally developed through instruction that merely emphasizes memorization of concepts. Environmental ethics requires students' active engagement in reasoning, reflection, and decision-making processes related to real-world environmental issues. Therefore, learning should be designed to provide opportunities for students to consider alternative solutions, evaluate the consequences of actions, and reflect on the values underlying their decisions.

One of learning approach that is relevant for developing scientific argumentation skills as well as environmental ethics is the Socio-Scientific Issues (SSI) approach. The SSI approach positions controversial social and environmental issues as learning contexts, thereby encouraging students to construct evidence-based arguments while simultaneously reflecting on the ethical implications of the decisions they make [14], [15]. Within the SSI context, students are not only required to construct scientific arguments but also to evaluate the moral, social, and environmental implications of various courses of action.

Previous researchs have demonstrated that SSI-based learning is effective in improving scientific argumentation skills, scientific literacy, and responsible decision-making abilities [16], [17]. However, the implementation of SSI in science education in Indonesia remains relatively limited. Teachers face constraints related to the availability and readiness of instructional materials, contextual learning resources, and systematic guidelines for integrating cognitive and affective aspects, including environmental ethics, into the learning process [18]. Although numerous studies have reported the effectiveness of Socio-Scientific Issues (SSI)-based learning in enhancing students' scientific argumentation and scientific literacy, most of these studies focus on classroom implementation and short-term intervention effects. Limited studies have systematically developed a comprehensive Subject-Specific Pedagogy (SSP) framework that integrates SSI within a structured curricular model, particularly in the Indonesian junior high school context. Moreover, prior research tends to emphasize cognitive outcomes, while the integration of environmental ethics as an explicitly operationalized and measurable construct within SSI-based instructional materials remains underexplored. Additionally, few development-oriented studies have contextualized SSI within locally relevant environmental issues, such as forest and peatland fires, which are socio-ecologically significant in Indonesia.

One of the way to contextualize science learning while enabling the systematic implementation of SSI-based instruction is through the use of an integrated learning model. One commonly applied integration model in science education is the webbed model, which focuses on a central theme to integrate various topics [19]. The themes used in the webbed model are generally derived from real-life phenomena encountered in daily life, such as forest and peatland fires areas.

The phenomenon of forest and peatland fires represents a scientific and social issue that can be effectively incorporated into science learning through the Socio-Scientific Issues (SSI) approach and integrated within the webbed integration model using the theme "Forest and peatland fires." Learning outcomes and competencies need to be carefully planned in a systematic manner. Learning designs intended to manage instructional processes in order to achieve expected outcomes are referred to as learning devices or instructional materials [20]. The development of instructional materials is closely related to the readiness of learning implementation. Previous studies have indicated that the development of instructional materials aligned with learners' needs can lead to optimal learning outcomes [21]; [22]

This study offers novelty in three major aspects. First, it develops an integrated Subject-Specific Pedagogy (SSP) framework that systematically embeds SSI stages within a webbed curriculum model and Problem-Based Learning syntax. Second, it operationalizes environmental ethics into measurable dimensions aligned with SSI learning activities, thus bridging cognitive argumentation skills and affective ethical development. Third, it contextualizes SSI within the locally relevant issue of forest and peatland fires, providing a regionally responsive instructional design. Therefore, this research contributes not merely to SSI implementation, but to the structured pedagogical development of SSI-based biology learning devices in the Indonesian context.

Based on the description, this study aims to develop a Subject-Specific Pedagogy (SSP) using the Socio-Scientific Issues approach on the theme of forest and peatland fires, manifested in the form of a teaching module, student worksheets, handouts, and assessment instruments. These products are intended to serve as valid science learning devices to support the enhancement of students' scientific argumentation skills and environmental ethics.

2. RESEARCH METHOD

This research is research and development that uses the Borg and Gall model which consists of 10 stages, such as 1) research and information collection, 2) planning, 3) develop preliminary form of product, 4) preliminary field testing, 5) main product revision, 6) main field testing, 7) operational product revision, 8) operational field testing, 9) final product revision, dan 10) dissemination and implementation [23]. However, the implementation of this study was limited to the product revision stage based on expert validation results, in accordance with the research objective, which focused on developing valid instructional materials that are ready to be further tested in subsequent studies examining empirical implementation, practicality, and effectiveness.

The Borg and Gall development model was selected because it provides a systematic framework for educational product development, emphasizing validation and refinement through expert review before field implementation. This model is particularly appropriate for developing instructional materials that require alignment among curriculum standards, pedagogical principles, and assessment instruments. Compared to simpler development models, Borg and Gall offers comprehensive procedural steps that ensure theoretical grounding, systematic revision, and product feasibility prior to empirical testing.

The development of the instructional materials was conducted with reference to the characteristics of junior high school science learning in South Kalimantan, particularly within the context of the theme of forest and peatland fires. This study did not involve classroom implementation or the collection of direct data from students.

The data collection instrument used in this study was the learning device validation sheet. The validation sheet is used to obtain assessments and input from expert validators regarding the appropriateness of content, construct, language, presentation, and suitability of the device with the Socio-Scientific Issues approach. The feedback provided by the validators served as the basis for revising the instructional materials until a final valid product was achieved.

The validation process involved two expert validators with expertise in science education and instructional material development. Both validators hold doctoral degrees in science education and have more than five years of experience in curriculum development and research related to scientific argumentation and Socio-Scientific Issues (SSI). The selection of validators was conducted purposively based on the following criteria: (1) academic qualification in science education, (2) experience in developing or evaluating science instructional materials, (3) familiarity with the Kurikulum Merdeka framework, and (4) research experience in scientific argumentation or environmental education. The involvement of qualified expert validators was intended to ensure the credibility, relevance, and theoretical alignment of the developed instructional materials prior to empirical testing.

Content validity was established through expert judgment involving two science education experts who evaluated the alignment between the instruments and the intended constructs. The validation process employed the Guttman scale to assess item relevance and clarity. The validity criteria were determined using the Coefficient of Reproducibility (CR) and Coefficient of Scalability (CS), following Guttman scaling procedures. Reliability estimation was conducted using internal consistency analysis. Instruments were considered reliable when CR values exceeded 0.90 and CS values exceeded 0.60, indicating acceptable scalability and consistency of the instrument structure.

This study was conducted in accordance with general research ethics principles. The development phase did not involve direct experimentation or intervention with students, as the study was limited to product development and expert validation. The expert validators participated voluntarily and provided informed consent prior to the validation process. All data obtained from validators were treated confidentially and used solely for research purposes. Since this research did not involve human subjects testing or the collection of personal student data, formal ethical clearance was not required at this stage of the study.

Data analysis was conducted using percentage analysis techniques to determine the level of validity of the instructional materials, as well as descriptive qualitative analysis to describe the suggestions and comments from expert validators as a basis for product refinement. Quantitative data from expert validation were analyzed using Guttman scale analysis to calculate the Coefficient of Reproducibility (CR) and Coefficient of Scalability (CS). The criteria for validity were determined as follows: instructional materials were categorized as valid if $CR \geq 0.90$ and $CS \geq 0.60$. Descriptive qualitative analysis was conducted on validators' comments and suggestions. These qualitative data were categorized into themes related to content improvement, language clarity, construct alignment, and SSI integration, and were used as the basis for systematic product revision.

3. RESULT AND DISCUSSION

This research and development study was conducted in two stages: product development results and product trial results. This article will focus on the product development results.

Research and Information Collection

The research and information collection stage produced several preliminary findings that served as the foundation for the development of the instructional materials. A needs analysis was conducted through interviews with science teachers, and the results were analyzed and translated into a learning design aligned with the identified problems. The interview results indicated that the implemented curriculum was the *Kurikulum Merdeka*, with student textbooks serving as the primary learning resources. However, the implementation of the Problem-Based Learning (PBL) model in science instruction had not been optimally carried out. In addition, the Socio-Scientific Issues (SSI) approach had never been implemented, and students' scientific argumentation skills and environmental ethics had not been systematically assessed.

The student analysis summarized the information obtained, indicating that students' learning interest and engagement were still relatively low. Only a small proportion of students demonstrated active participation in the learning process, such as asking questions, responding to teachers' questions, or expressing opinions. In terms of thinking skills, students' scientific argumentation abilities were also limited. Students tended to express opinions without providing adequate reasoning, data, or scientific evidence, resulting in arguments that did not yet reflect complete scientific reasoning.

Curriculum analysis was conducted to examine the components of the *Kurikulum Merdeka*, focusing on learning outcomes (*Capaian Pembelajaran*) and learning objectives (*Tujuan Pembelajaran*). This analysis aimed to ensure that the developed instructional materials were aligned with curricular demands. The selected content covered ecology and biodiversity in Indonesia, which was framed within the contextual theme of "forest and peatland fires." This theme was chosen due to its relevance to environmental conditions in South Kalimantan and its strong potential to be addressed as a socio-scientific issue.

Concept analysis was carried out to identify the underlying science concepts related to the learning materials, including facts, concepts, principles, laws, and theories associated with ecosystems and biodiversity. The results of this analysis served as a reference for designing learning materials and activities that are consistent with the disciplinary structure of science education.

Based on the aforementioned analyses, several key issues were identified, indicating the need for the targeted development of instructional materials. These issues included students' low levels of scientific argumentation skills, less positive learning attitudes toward science learning, and the limited availability of contextual and relevant learning resources. These conditions have contributed to suboptimal learning processes and provide a strong rationale for the development of innovative instructional materials integrated with real-world issues relevant to students' environments.

Planning

The planning stage was conducted based on the results of the needs analysis, student analysis, curriculum analysis, and concept analysis. At this stage, the design of instructional materials integrated with the webbed integration model using the Socio-Scientific Issues (SSI) approach was established to train students' scientific argumentation skills while fostering environmental ethics. The identified instructional material requirements were aligned with the findings of the initial needs analysis, student analysis, curriculum analysis, and concept analysis. Accordingly, instructional materials integrated with the webbed model and SSI approach were determined to support the development of students' scientific argumentation and environmental ethics.

The instructional materials were designed to include three main subtopics: the influence of environmental factors on organisms, interactions among ecosystem components, and human impacts on ecosystems. These subtopics were integrated into a single central theme, namely forest and peatland fires, which was examined through a socio-scientific issues perspective. This approach enables students to connect scientific concepts with real-world environmental problems while considering scientific, social, and environmental ethical aspects in decision-making processes.

The selection of the instructional material format was carried out to ensure compliance with appropriate criteria for learning materials, making them suitable for classroom implementation. Science content on ecology and biodiversity in Indonesia was integrated with the Problem-Based Learning (PBL) model as the primary instructional framework. The integration of PBL and SSI was designed to encourage students' active engagement in problem-solving, promote the development of evidence-based arguments, and facilitate reflection on environmental ethical values.

The results of the planning process regarding the integration of SSI aspects into the instructional materials were subsequently presented in the form of a mapping of SSI stages embedded within learning activities, as shown in Table 1.

Table 1. Design of SSI Aspects in Products

Meeting	SSI Stages	Explanation
1st meeting	<i>Problem Analysis</i>	Students observe images of peat ecosystems, the flora and fauna that make up peat, and are introduced to peatlands, as well as issues of peat vulnerability and the threat of destruction.
	<i>Clarification of Science</i>	Explanations of biotic and abiotic components; the elements, compounds, and mixtures that make up peat; and the peat ecosystem food web.
	<i>Refocus on Socio-Scientific Dilemma</i>	Answers socio-scientific issues regarding the use of peat for economic purposes and environmental conservation
2nd meeting	<i>Role Play</i>	Each group acts as a key role, such as scientists, entrepreneurs, farmers, and government (decision makers), each with its own focus
	<i>Meta reflective activity</i>	Reflective issues address environmental awareness, empathy for various parties, and the role of students in fire prevention
3rd meeting	<i>Problem Analysis</i>	Identifying the causes of fires and introducing the issues of land clearing by fire, drought, and the health and economic impacts
	<i>Clarification of Science</i>	Discussing oxidation reactions, the fire triangle, and the chemical elements of peat.
	<i>Refocus on Socio-Scientific Dilemma</i>	Addressing the dilemma of how humans contribute to forest fires and their impacts on humans, such as acute respiratory infections (ARI).
4th meeting	<i>Role Play</i>	Pro-contra debate on the motions "companies that destroy peat must be shut down" and "communities need to be incentivized not to burn land."
	<i>Meta-Reflective Activity</i>	Internalization of environmental values and concrete actions that can be taken to protect the environment.
5th meeting	<i>Problem analysis</i>	Analyzes articles about the difficulty of extinguishing peatlands and the flammable nature of peat.
	<i>Clarification of Science</i>	Examines the causes of forest and peatland fires and possible solutions to prevent/manage them.
	<i>Refocus on Socio-Scientific Dilemma</i>	Addresses the dilemma of expensive, environmentally friendly farming methods versus old, cheap, but environmentally damaging methods.
	<i>Role Play</i>	Debates on fire prevention innovations based on existing innovation articles.
	<i>Meta-Reflective Activity</i>	Contains a tree of hope for students to attach with sticky notes containing small actions to protect the environment.

Develop Preliminary Form of Product

The develop preliminary form of product stage resulted in the initial design of instructional materials in the form of a teaching module and student worksheets integrated with the Problem-Based Learning (PBL) model and the Socio-Scientific Issues (SSI) approach. The developed teaching module was systematically organized with careful consideration of its alignment with the *Kurikulum Merdeka* and the characteristics of the students.

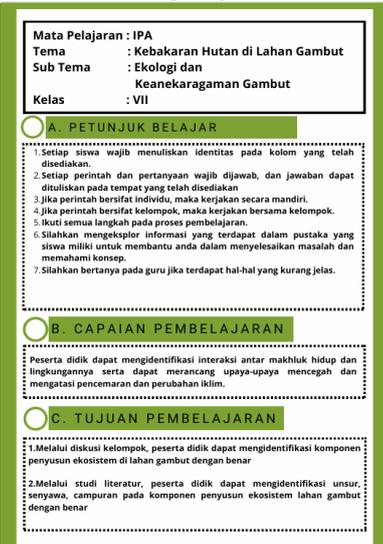
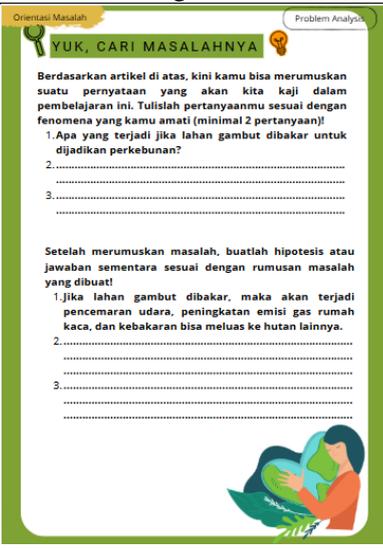
The teaching module consisted of several main components: (a) general information, including developer identity, the *Pancasila Student Profile*, learning facilities and infrastructure, student characteristics and learning targets, as well as the learning model and approach employed; and (b) core components, which comprised learning objectives, triggering questions, learning activity syntax, reflection activities, assessment, and plans for remedial and enrichment learning. All components were designed to support the implementation

of problem-based learning oriented toward strengthening students' scientific argumentation skills and environmental ethics.

The learning activities in the teaching module were structured according to the PBL syntax integrated with SSI stages. This integration was realized through the presentation of contextual problems related to forest and peatland fires, data- and evidence-based discussions, and reflective activities that encouraged students to consider scientific, social, and environmental ethical aspects when formulating arguments and solutions.

To support the implementation of the teaching module, student worksheets and handouts were developed as guides for student activities during the learning process. The worksheet was designed to facilitate scientific argumentation skills through activities such as identifying problems, formulating claims, constructing evidence-based reasoning, and reflecting on the environmental impacts of decisions. The initial worksheet design was presented in the form of a development draft, as shown in Table 2.

Table 2. Worksheet Components

Worksheet Components	
Worksheet Cover	Learning Instructions, Learning Outcomes, and Learning Objectives
	
Subject	Learning Activities
	
Learning Activities	

Worksheet Components

AYO PAHAM LEBIH DALAM

Berdasarkan pertanyaan nomor 1 dan 2 sebelumnya, identifikasi lebih dalam dengan menjawab soal dibawah ini

Dari kelompok abiotik yang kalian temukan, coba identifikasi mana yang termasuk unsur, senyawa, atau campuran (dengan mencentangnya). Jelaskan kenapa kalian mengelompokkannya demikian.

Komponen	Termasuk			Alasan Pengelompokan
	Unsur	Senyawa	Campuran	
O ₂				
H ₂ O				
H ₂				
CO ₂				
CH ₄				

AYO KITA LAKUKAN!

Mari lakukan penyelidikan untuk menjawab rumusan masalah yang telah diajukan dan membuktikan jawaban sementara yang kamu buat!

A. Merencanakan Penyelidikan
 Alat dan Bahan : Gawai, Internet, Alat tulis

B. Langkah-langkah penyelidikan

1. Bentuklah kelompok yang terdiri dari 3-5 orang!
2. Carilah informasi dari berbagai sumber terpercaya
3. Diskusikan bersama kelompok kalian tentang isunya

Kelompok

Membimbing Penyelidikan

AYO SELIDIKI ISUNYA

Bila lahan gambut rusak parah, bisa dibayangkan risiko peningkatan emisi gas rumah kaca yang menyebabkan pemanasan global semakin cepat. Selain itu, kerusakan gambut juga berkontribusi terhadap bencana lingkungan, seperti kebakaran hutan, hilangnya keanekaragaman hayati, serta risiko banjir dan kekeringan yang semakin sering terjadi.

Namun, di sisi lain, lahan gambut juga memiliki nilai ekonomi yang tinggi. Banyak masyarakat menggantungkan hidup dari hasil perkebunan, pertanian, dan industri yang berkembang di kawasan gambut. Perusahaan besar mengelola lahan ini untuk menghasilkan komoditas seperti sawit dan karet, yang menjadi salah satu sumber pendapatan bagi negara dan membuka lapangan pekerjaan bagi banyak orang.

Disinilah muncul dilema besar: 1) Apakah kita harus terus memanfaatkan lahan gambut demi kepentingan ekonomi meskipun ada risiko besar terhadap lingkungan? 2) bisakah kita menemukan cara agar ekonomi tetap berkembang tanpa merusak lingkungan? 3) Apakah ekonomi dan lingkungan bisa berjalan berdampingan?, jelaskan!

This handout was developed as supporting teaching material to help students understand key concepts and the socio-scientific context of forest and peatland fires. It contains a summary of the material and supporting information presented visually and contextually. The handout was created using the web-based Canva application and exported as a PDF. The handout development draft is presented in Table 3.

Table 3. Handout Components

Handout Components

Cover	Instructions for use
	<div style="border: 1px solid black; padding: 10px;"> <p style="text-align: center;">Petunjuk Penggunaan</p> <ol style="list-style-type: none"> 1. Pahami Tujuan Handout: Sebelum memulai, penting untuk memahami tujuan dari handout ini. Fokuskan perhatian pada pembahasan tentang isu socio-ilmiah yang terkait dengan kebakaran hutan di lahan gambut, serta dampaknya yang luas. 2. Baca Dengan Teliti: Bacalah isi handout secara cermat dan teliti. Setiap bagian disusun dengan tujuan tertentu, termasuk informasi, data, dan analisis yang relevan dengan tema kebakaran hutan di lahan gambut. 3. Refleksikan Materi: Setelah membaca setiap bagian, luangkan waktu untuk merenungkan dan merefleksikan materi yang telah dipresentasikan. Pertimbangkan implikasi sosial, lingkungan, dan ilmiah dari isu kebakaran hutan ini. 4. Diskusikan Bersama: Handout ini juga dapat digunakan sebagai bahan diskusi. Anda dapat membahasnya bersama teman, keluarga, atau rekan kerja untuk memperluas pemahaman dan mendapatkan beragam sudut pandang. 5. Perluas Pengetahuan: Gunakan handout ini sebagai titik awal untuk memperluas pengetahuan Anda tentang kebakaran hutan di lahan gambut. Telusuri referensi tambahan yang disediakan untuk mendapatkan informasi lebih lanjut tentang topik ini. 6. Berkarya: Selanjutnya, gunakan pengetahuan yang Anda dapatkan dari handout ini sebagai inspirasi untuk bertindak. Pikirkan langkah-langkah konkrit yang dapat Anda ambil untuk mengatasi masalah kebakaran hutan ini, baik secara individu maupun bersama komunitas Anda. 7. Bersikap Proaktif: Ingatlah bahwa isu kebakaran hutan di lahan gambut membutuhkan tindakan nyata. Jadilah bagian dari solusi dengan melakukan langkah-langkah yang mendukung pelestarian lingkungan dan penanganan isu sosial yang terkait. <p style="text-align: center;">4</p> </div>
Introduction	Learning Outcomes and Learning Objectives

Handout Components

Pendahuluan

Selamat mencermati dan memahami handout pembelajaran ini yang didedikasikan untuk memahami lebih dalam tentang kebakaran hutan di lahan gambut, sebuah isu yang kompleks dan mendesak dalam konteks lingkungan dan sosial saat ini.

Sebelum kita memasuki inti materi, mari kita menguraikan secara singkat apa yang dimaksud dengan kebakaran hutan di lahan gambut dan prasyarat yang perlu dipahami sebelum mempelajari topik ini dengan lebih lanjut.

Kebakaran hutan di lahan gambut adalah fenomena yang memiliki dampak serius tidak hanya pada lingkungan, tetapi juga pada kehidupan manusia dan keberlanjutan ekosistem. Lahan gambut, yang merupakan ekosistem penting dan sensitif, rentan terhadap kebakaran karena kandungan material organik yang tinggi dan kecenderungan terbakarnya yang mudah ketika kering.

Kebakaran hutan di lahan gambut memiliki konsekuensi yang luas, termasuk emisi gas rumah kaca yang berkontribusi pada perubahan iklim global, kerugian biodiversitas, hilangnya habitat satwa liar, dan dampak sosio-ekonomi bagi masyarakat lokal yang bergantung pada sumber daya alam tersebut.

Sebelum mempelajari materi dalam handout ini, alangkah lebih baiknya Anda sudah mempelajari dan memahami materi tentang "Klasifikasi Makhluk Hidup"

5

Capaian Pembelajaran

Peserta didik dapat mengidentifikasi interaksi antar makhluk hidup dan lingkungannya serta dapat merancang upaya-upaya mencegah dan mengatasi pencemaran dan perubahan iklim

Tujuan Pembelajaran

Tujuan Pembelajaran berisi:

- Melalui studi literatur, peserta didik dapat mengidentifikasi komponen penyusun ekosistem di lahan gambut dengan benar
- Melalui studi literatur, peserta didik dapat mengidentifikasi unsur, senyawa, campuran pada komponen penyusun ekosistem lahan gambut dengan benar
- Melalui diskusi kelompok, peserta didik dapat menganalisis kegiatan manusia yang dapat menyebabkan kebakaran hutan di lahan gambut dan dampaknya terhadap lingkungan, sosial dan ekonomi dengan benar
- Melalui diskusi kelompok, peserta didik dapat menghubungkan pengaruh factor suhu dan unsur senyawa penyusun gambut terhadap penyebab terjadinya kebakaran hutan di lahan gambut dengan benar
- Melalui diskusi dan presentasi kelompok, peserta didik dapat mengidentifikasi pentingnya konservasi keanekaragaman hayati dengan benar
- Melalui bermain peran, peserta didik dapat memberikan argumentasi berbagai solusi dari permasalahan lingkungan dengan percaya diri
- Melalui diskusi kelompok, peserta didik dapat mengembangkan sikap peduli lingkungan dan tanggung jawab individu melalui tindakan sederhana, seperti membuang sampah pada tempatnya, dan mendukung konservasi.

6

Issues related to material

Isu Terkait Materi



Ekosistem Gambut di Kalimantan Terancam
 Karhutla yang bertumbuh luas di sejumlah daerah Provinsi Kalimantan Selatan telah mengancam ekosistem gambut di wilayah ini
18 | www.kompas.com, 10/11/2022

Sumber: Media Indonesia



Lahan Gambut di Kalimantan Selatan Mudah Terbakar dan Sulit Dipadamkan
 Lahan gambut di Kalimantan Selatan semakin mudah terbakar dan sulit dipadamkan. SIBR menemukan dua 'helikopter' 'water bombing' untuk membantu pemadaman karhutla di Kalimantan.
10 | www.kompas.com, 10/11/2022

Sumber: Harian Kompas

Kebakaran hutan di lahan gambut telah menjadi masalah yang semakin mendesak, dengan dampak yang meluas dari kerusakan lingkungan hingga dampak langsung pada kesehatan masyarakat dan ekonomi lokal. Wilayah Kalimantan Selatan, dengan kekayaannya yang luar biasa, tidak luput dari ancaman ini. Sebelum kita membahas lebih lanjut, mari kita baca sampai tuntas dua berita diatas.

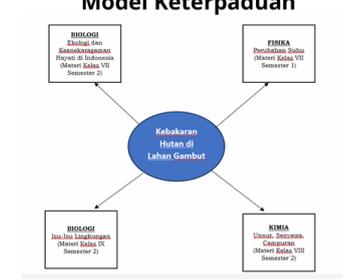
7

Integrated model

Pembelajaran IPA terpadu merupakan suatu pendekatan pembelajaran IPA yang menghubungkan atau menyatupadukan berbagai bidang kajian IPA menjadi satu kesatuan bahasan. Pembelajaran IPA membutuhkan model keterpaduan yang sesuai agar hasil belajar yang didapat peserta didik juga maksimal (Fogarty, 1991).

Handout ini menggunakan salah satu model keterpaduan yang dikembangkan Fogarty (1991), yaitu model keterpaduan Webbed dengan menggunakan tematik sebagai pendekatan untuk mengintegrasikan konten belajar

Model Keterpaduan



Gambar 1. Webbed (Fogarty)

8

Teaching materials

Ekologi dan Keanekaragaman Makhluk Hidup di Indonesia

Indonesia, dengan keanekaragaman hayati yang luar biasa, merupakan salah satu negara terkaya akan spesies-spesies makhluk hidup di dunia. Keunikan geografisnya, mulai dari hutan hujan tropis, lahan gambut, hingga terumbu karang, menciptakan beragam habitat yang mendukung kehidupan yang berlimpah.

Hutan Hujan Tropis: Hutan hujan tropis Indonesia adalah rumah bagi berbagai jenis flora dan fauna, termasuk spesies endemik yang hanya ditemukan di Indonesia, seperti orangutan Sumatera dan harimau Jawa.

Lahan Gambut: Lahan gambut Indonesia, yang mencakup sebagian besar pulau Kalimantan dan Sumatera, merupakan ekosistem unik dengan vegetasi khas seperti pohon-pohon gambut, lumut, dan pakis. Habitat ini penting bagi spesies langka seperti orangutan Kalimantan dan harimau Sumatera.

Terumbu Karang: Perairan Indonesia dikenal karena keindahan terumbu karangnya yang luar biasa. Terumbu karang ini mendukung kehidupan yang sangat beragam, termasuk ikan-ikan warna-warni, terumbu karang keras, dan hewan-hewan laut lainnya.

9

Komponen Penyusun Ekosistem Gambut

Karnivora:



Gambar 13. Macan dahlan Kalimantan (Neofelis diardi borneensis)



Gambar 14. Harimau Sumatera (Panthera tigris sumatrae)

Omnivora:



Gambar 15. Burung Enggang / rangkong badak (Buceros rhinoceros)



Gambar 16. Orang utan (Pongo pygmaeus)

Dekomposer: Mikroorganisme seperti bakteri, jamur, dan cacing tanah yang membantu menguraikan sisa-sisa organik menjadi bahan penyubur tanah.

Q 2. Komponen Abiotik (Tak Hidup)

Komponen ini meliputi faktor-faktor lingkungan yang mempengaruhi ekosistem gambut, seperti:

- Tanah Gambut: Tanah organik yang kaya akan bahan organik terdekomposisi, bersifat asam, dan memiliki kemampuan menyimpan air dalam jumlah besar.
- Air: Tingkat kelembaban yang tinggi mendukung keberlanjutan ekosistem gambut.
- Iklim: Curah hujan tinggi dan suhu tropis berperan dalam pembentukan dan pelestarian gambut.
- Cahaya Matahari: Mendukung fotosintesis tumbuhan sebagai produsen utama.

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The instruments used in this study consisted of a product evaluation instrument and a scientific argumentation skills test. The product evaluation instrument was employed to assess the feasibility of the developed science instructional materials, including the teaching module, student worksheets, handouts, and assessment instruments. The evaluation was conducted by expert validators by considering aspects of content feasibility, presentation, language use, and the alignment of the instructional materials with the characteristics of the learning model and the Socio-Scientific Issues (SSI) approach.

The scientific argumentation skills test was developed based on a synthesis of expert perspectives referring to the Toulmin argumentation framework. The aspects of scientific argumentation measured in this study included claim, data, warrant, and backing. These four aspects were selected because they represent the fundamental structure of scientific argumentation relevant to the context of junior high school science learning.

Based on the indicators of each scientific argumentation aspect, the researchers constructed a multiple-choice test consisting of 20 items, each with four answer options. Each test item was designed using the context of forest and peatland fires to encourage students to connect scientific concepts with real socio-scientific issues. The test instrument was subsequently included as part of the developed assessment package and was validated by experts to ensure content relevance, construct appropriateness, and readability.

An environmental ethics questionnaire was developed to measure students' attitudes toward the environment within the context of SSI-based science learning. The development of the environmental ethics questionnaire was guided by nine dimensions of environmental ethics: (1) respect for nature, (2) the principle of responsibility, (3) the principle of care and compassion for nature, (4) the principle of living simply and in harmony with nature, (5) the no-harm principle, (6) cosmic solidarity, (7) the principle of justice, (8) the principle of democracy, and (9) the principle of moral integrity. Each dimension was elaborated into several attitude indicators adjusted to the characteristics of junior high school students and the specific regional context.

Based on these indicators, the researchers developed an environmental ethics questionnaire consisting of 37 statements presented in the form of a Likert scale. The questionnaire was designed to reveal students' tendencies in evaluating, responding to, and making decisions regarding socio-scientific environmental issues. The environmental ethics questionnaire was subsequently validated by experts to ensure content appropriateness, clarity of statements, and readability before being used as part of the developed instructional materials.

Results of Teaching Module Validation

The science instructional materials in the form of a teaching module integrated with the webbed model and the Socio-Scientific Issues (SSI) approach were developed in accordance with the *Kurikulum Merdeka*. The aspects evaluated by expert lecturers for the teaching module included: (a) module components, (b) learning activities, (c) learning steps, and (d) appendices. Based on the validation results, the expert lecturers provided several suggestions for improvement, including refining the formulation of learning objectives to better align with the learning outcomes, adding the Learning Objectives Flow (*Alur Tujuan Pembelajaran*), and adjusting the learning model from discovery learning to Problem-Based Learning (PBL) to better match the characteristics of the SSI approach and the objective of training scientific argumentation skills. These suggestions were used as the basis for revising the developed teaching module. The results of the teaching module feasibility assessment by the expert lecturers are presented in Table 4.

Table 4. Teaching Module Feasibility Assessment Results

Aspects	CR	CR	CS	CS	Explanation
	Calculation Results (%)	Standard (%)	Calculation Results (%)	Standard (%)	
Teaching Module Components	97,5	90	95	60	Valid
Learning Activities	100	90	100	60	Valid
Learning Steps	96	90	93	60	Valid
Appendix	100	90	100	60	Valid

Based on Table 4, it can be concluded that the validity assessment data on the teaching module in each aspect is declared valid or suitable for use with a Coefficient of Reproducibility (CR) value of > 90% and a Coefficient of Scalability (CS) value of > 60%. Therefore, it can be stated that the developed teaching module meets the validity criteria. Thus, the integrated teaching module of the webbed model with the SSI approach is declared valid and suitable for use as a learning tool to train students' scientific argumentation skills and environmental ethics.

Worksheet Validation Results

The science learning tool, a web-based integrated worksheet with an SSI approach, was developed based on the *Kurikulum Merdeka*. The aspects assessed by expert lecturers for the teaching module included: a) content, b) design, and c) language. Based on the validation results, the expert lecturers provided several input for improvements, including adjusting the worksheet activities to the learning syntax used and adding markers or captions indicating activity sections that represent SSI stages and learning syntax. This input was used as the basis for revising the worksheet to make it more systematic and easier for students to understand. The results of the worksheet feasibility assessment by expert lecturers are presented in Table 5.

Table 5. Worksheet feasibility assessment results

Aspects	CR Calculation Results (%)	CR Standard (%)	CS Calculation Results (%)	CS Standard (%)	Explanation
Content	92	90	85	60	Valid
Design	100	90	100	60	Valid
Language	100	90	100	60	Valid

Based on Table 5, it can be concluded that the validity assessment data for the Student Worksheet in each aspect is valid or suitable for use, with a Coefficient of Reproducibility (CR) value of >90% and a Coefficient of Scalability (CS) value of >60%. Therefore, the developed worksheet is valid and suitable for use as a supporting learning tool in science learning using the SSI approach to train students' scientific argumentation skills and environmental ethics.

Handout Validation Results

The science learning tool, a web-based integrated handout with the SSI approach, was developed based on the *Kurikulum Merdeka*. The aspects assessed by the expert lecturer for the teaching module included: a) content, b) design, and c) language. Based on the validation results, the expert lecturer provided input for improvements in the form of adding a list of figures, adjusting the text color for better legibility, and adding relevant illustrations, such as producers, herbivores, carnivores, omnivores, decomposers, and food webs in peatland ecosystems. This input was used to refine the handout to make it more contextual and support students' conceptual understanding. The following are the results of the handout assessment based on the expert lecturer's validation assessment, presented in Table 6.

Table 6. Handout Feasibility Assessment Results

Aspects	CR Calculation Results (%)	CR Standard (%)	CS Calculation Results (%)	CS Standard (%)	Explanation
Competence	100	90	100	60	Valid
Quality of Material	95	90	80	60	Valid
Completeness of Material	100	90	100	60	Valid

Based on Table 6, it can be concluded that the validity assessment data for each aspect of the handout is valid or suitable for use, with a Coefficient of Reproducibility (CR) value of >90% and a Coefficient of Scalability (CS) value of >60%. Therefore, the developed handout is valid and suitable for use as a supporting learning resource in SSI-based science learning.

Scientific Argumentation Test Instrument Validation Results

The scientific argumentation skills test instrument was developed to measure students' ability to construct and evaluate scientific arguments in the context of Socio-Scientific Issues (SSI)-based science learning. This instrument is structured based on the Toulmin argumentation framework, which includes four main components: claim, data, warrant, and backing. The questions consist of 20 multiple-choice items covering indicators of scientific argumentation. The format is presented as a narrative essay/news item, followed by four questions each containing scientific argumentation practice indicators of claim, evidence, warrant, and backing. The outline for scientific argumentation questions can be seen in Table 7.

Table 7. Scientific Argumentation Outline

No	Indicator	Number of Questions
1	<i>Claim</i> : Selecting a claim about the issue related to the narrative.	5
2	<i>Evidence</i> : Analyzing data to support the claim about the issue related to the narrative.	5

No	Indicator	Number of Questions
3	<i>Warrant</i> : Explaining the relationship between the data and the claim.	5
4	<i>Backing</i> : Creating supporting justification to support the claim based on theories related to the narrative	5

Test instrument validation was conducted by expert lecturers to assess the instrument's suitability before use in the empirical testing phase. Aspects assessed in instrument validation included: (a) material (question items align with learning outcomes and align with the scientific argumentation indicators used); (b) construction (question instructions are provided; questions are worded using clear questions or commands; reading text and tables are clearly legible and visible; and there is only one correct answer); and (c) language (sentences are formulated using communicative language; sentences are formulated using common language that students can understand, and words used are free from ambiguous meanings).

Based on the validation results, expert lecturers provided input in the form of improving the wording of several questions to make them more contextual, adjusting the question wording, adding infographics from the narratives presented to stimulate students' scientific argumentation, and emphasizing the relationship between answer options and the scientific argumentation indicators being measured. This input was used as the basis for revising the test instrument to more effectively measure students' scientific argumentation skills

The results of the validation analysis show that the scientific argumentation skills test instrument meets the validity criteria based on the Coefficient of Reproducibility (CR) value > 90% and Coefficient of Scalability (CS) > 60%, so that the instrument is declared valid and suitable for use as a measuring tool for scientific argumentation skills in science learning using the SSI approach.

Environmental Ethics Questionnaire Instrument Validation Results

The environmental ethics questionnaire instrument was developed to measure students' environmental ethical attitudes in Socio-Scientific Issues (SSI)-based science lessons on the topic of forest and peatland fires. The questionnaire was based on nine dimensions of environmental ethics relevant to the learning context: respect for nature, the principle of responsibility, the principle of compassion and care for nature, the principle of living simply and in harmony with nature, the principle of no harm, cosmic solidarity, the principle of justice, the principle of democracy, and the principle of moral integrity.

Each dimension is described in several attitude indicators, as presented in Table 8. These indicators were formulated to represent observable and measurable environmental ethical attitudes in junior high school students and were contextualized with real-life environmental issues, specifically forest and peatland fires. Based on these indicators, 37 statements were compiled on a Likert scale that reflect students' attitudinal tendencies toward the environment.

Table 8. Environmental Ethics Questionnaire Outline

No.	Dimention	Indicator	Number of Statements
1.	Respect for nature	Respect for all life	3
		Maintaining socio-ecological cohesion	
		Respecting the rights of nature	
2.	Principle of responsibility	Maintaining environmental sustainability	4
		Caring for the universe	
3.	Principle of compassion and concern for nature	Compassion for nature	4
		Preventing harm to animals	
		Preventing actions that could harm nature	
4.	Principle of living simply and in harmony with nature	Utilizing open land	5
		Limiting consumer behavior	
		In harmony with nature	
5.	Principle of "no harm"	Avoiding harm to nature	3
		Preventing threats to the environment (no harm)	
		Replacing raw materials for fashion	
6.	Cosmic solidarity	Supporting conservation	5
		Feelings of sadness over the destruction of nature	
		Prioritizing environmental concerns	
		Utilizing plastic waste	
7.	Principle of justice	Gender equality for equal access to natural resources	4

No.	Dimention	Indicator	Number of Statements
		Procedural justice in the environment	
		Protection of natural resources for future generations	
8.	Principle of democracy	Democracy provides the widest possible space for diversity	5
		Everyone participates in determining public policy	
		Public accountability	
9.	Principle of moral integrity	Not sacrificing environmental interests	4
		Moral behavior towards nature	
		Responsible	
Amount			37

The validation of the environmental ethics questionnaire was conducted by expert lecturers to assess the instrument's feasibility prior to its empirical testing stage. The aspects evaluated in the validation process included: (a) identity, (b) objectives, (c) instructions for completion, and (d) statement items.

Based on the validation results, the experts provided several suggestions for improvement, including refining the wording to ensure that statements were more communicative and unambiguous, avoiding the use of negative sentences, and strengthening the alignment between the statements and the environmental ethics indicators being measured. All feedback was used as the basis for revising the environmental ethics questionnaire, resulting in an instrument that is more representative and easier for students to understand.

The validation analysis indicated that the environmental ethics questionnaire met the criteria for validity, with a Coefficient of Reproducibility (CR) exceeding 90% and a Coefficient of Scalability (CS) exceeding 60% for each dimension. Therefore, the developed environmental ethics questionnaire was deemed valid and suitable for use as an instrument to measure students' environmental ethics attitudes in SSI-integrated science learning.

Feasibility of Subject Specific Pedagogy Using Socio-Scientific Issues

The feasibility of the Subject Specific Pedagogy (SSP), embodied in SSI-based science learning materials, was evaluated by two expert lecturers from the science education program to obtain feasibility data. The product evaluation process was conducted using a validation sheet based on the Guttman scale. The results of expert validation indicated that the developed SSI-based SSP met feasibility criteria from conceptual, pedagogical, and contextual aspects. The integration of the webbed curriculum model enables various science concepts to be interconnected through a central theme, thereby supporting holistic and meaningful learning. This model was considered effective in helping students understand the interrelationships among scientific concepts through real-life contexts [19], [20]

The selection of forest and peatland fires as the learning context provided a high degree of contextual relevance, particularly for students in South Kalimantan. Science learning that is connected to local issues has been shown to enhance learning relevance, student engagement, and deeper conceptual understanding [15], [24]. Accordingly, the developed SSP demonstrates strong potential to bridge the gap between abstract scientific concepts and the environmental realities faced by students.

The perspective of scientific argumentation skill development, the SSI approach integrated into the SSP provides ample opportunities for students to engage in discussion, dialogue, and evidence-based decision-making. Scientific argumentation is an essential practice in science education that contributes to the strengthening of scientific literacy and critical thinking skills [25]. The learning structure, which adopts a Problem-Based Learning (PBL) model within the SSI context, allows students to construct arguments that include claims, data, warrants, and backing, as emphasized in Toulmin's argumentation framework [11], [26]

Beyond cognitive and argumentative aspects, the integration of environmental ethics into the SSP represents a significant contribution of this study. Contemporary science education emphasizes that learning objectives extend beyond conceptual mastery to include the development of students' attitudes, values, and moral responsibility toward the environment [27], [28]. The SSI approach inherently incorporates ethical dimensions, as it requires students to consider the moral, social, and environmental implications of science-based decisions [29], [30]

The validation results of the environmental ethics questionnaire indicate that the dimensions of environmental ethics were operationalized clearly and were relevant to the learning context. Dimensions such as responsibility toward nature, the principle of no harm, cosmic solidarity, and moral integrity align with the environmental ethics framework proposed by Keraf and with environmental education approaches that emphasize the integration of cognitive and affective aspects [31], [32]. Thus, the SSI-based SSP has the potential not only to enhance students' scientific argumentation skills but also to foster ethical awareness and attitudes toward environmental issues.

The findings of this study are consistent with previous research indicating that SSI-based learning materials are valid, feasible, and have the potential to improve students' scientific argumentation, scientific literacy, and ethical decision-making [14], [33], [34], [35]. High validity across content, pedagogy, and assessment aspects suggests that SSI-based learning materials represent a relevant alternative for addressing the demands of the *Kurikulum Merdeka* and the development of 21st-century competencies.

The findings of this study are consistent with previous research reporting that Socio-Scientific Issues (SSI)-based instructional materials are valid and feasible for enhancing students' scientific argumentation and decision-making skills [15], [29]. Similar to studies conducted by [16], [17] this research confirms that embedding controversial environmental issues within science learning promotes structured reasoning and ethical reflection. However, most prior studies focused primarily on classroom implementation and the measurement of learning outcomes, whereas the present study emphasizes systematic pedagogical development through a validated Subject-Specific Pedagogy (SSP) framework.

Furthermore, while previous SSI research predominantly highlighted cognitive outcomes such as argumentation and scientific literacy, the present study extends the discussion by operationalizing environmental ethics into measurable dimensions. The integration of ethical reflection within SSI stages aligns with the informal reasoning framework proposed by [29], yet advances it by embedding explicit ethical constructs such as responsibility, justice, and moral integrity into structured learning devices.

Compared to studies that applied SSI in generic global contexts (e.g., biotechnology or energy issues), this research contextualizes SSI within the locally relevant issue of forest and peatland fires. Contextualization has been emphasized by Sadler [15] as a critical factor in enhancing meaningful engagement. Therefore, this study strengthens the empirical support for contextual SSI implementation within Indonesian science education, particularly in regions directly affected by environmental degradation.

SSI Triggers Scientific Argumentation Structure

The SSI framework structurally facilitates the development of scientific argumentation by situating learning within controversial and open-ended real-world problems. The stages of problem analysis and clarification of science explicitly require students to formulate claims supported by scientific evidence. Role-play and debate activities stimulate the articulation of warrants and backing, as students must justify their positions using scientific principles and contextual data. Furthermore, exposure to counter-arguments during socio-scientific dilemmas promotes the development of rebuttals, thereby aligning with the Toulmin Argument Pattern. Thus, SSI does not merely provide contextual issues, but structurally scaffolds the complete architecture of scientific argumentation.

SSP Forms the Dimension of Environmental Ethics

Conceptually, the developed SSP integrates environmental ethics through reflective and meta-reflective activities embedded within SSI stages. Ethical dimensions such as responsibility, justice, and moral integrity are not treated as abstract values but are operationalized through decision-making scenarios. The structured inclusion of ethical reflection after argumentation activities enables students to move from cognitive reasoning toward value internalization. Therefore, the SSP bridges scientific reasoning and ethical consciousness within a coherent pedagogical structure.

Overall, this study does not merely confirm previous findings regarding the effectiveness of SSI-based learning, but contributes a structured and validated pedagogical model that integrates cognitive argumentation skills and environmental ethical dimensions within a coherent curriculum framework. Although this study was limited to the development and validation stages, the results provide a strong foundation for proceeding to empirical testing, as well as practicality and effectiveness evaluations. Future research is recommended to empirically examine the impact of implementing SSI-based SSP on students' scientific argumentation skills and environmental ethics, as well as to explore the relationship between these two variables within the context of science learning.

4. CONCLUSION

This study contributes theoretically by proposing an integrated framework of SSI-based Subject-Specific Pedagogy that connects scientific argumentation structure with environmental ethical dimensions within a webbed curriculum model. The study expands the conceptualization of SSI implementation by embedding measurable ethical constructs into structured biology learning devices. Practically, the developed SSP provides teachers with validated instructional materials that systematically integrate cognitive and affective competencies, aligned with the *Kurikulum Merdeka*. The contextualization of forest and peatland fires enhances the relevance of biology learning to local environmental realities. From a policy perspective, this development supports curriculum reform efforts emphasizing 21st-century competencies, sustainability education, and contextual learning. The SSP demonstrates broad implementation potential across regions with similar

environmental contexts and may serve as a model for developing other SSI-based instructional themes in biology education.

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