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REVIEW

# Navigating Controversy in the Science Classroom: Indonesian Biology Lecturers' Approaches to Socio-Scientific Issue Discussions

## Navegando la Controversia en el Aula de Ciencia: Enfoques de los Profesores de Biología Indonesios en las Discusiones sobre Problemas Socio-Científicos

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## ABSTRACT

**Introduction:** the incorporation of Socio-Scientific Issues (SSI) in science education has become an effective pedagogical strategy for enhancing students' critical thinking, ethical reasoning, and scientific literacy. In Indonesia, characterized by cultural diversity and curricular limitations, there is a limited understanding of how biology lecturers address contentious scientific subjects in the classroom. Notwithstanding the increasing global focus on SSI-based pedagogy, its application in Indonesian higher education remains insufficiently examined. This study investigates the understanding, behaviors, and obstacles encountered by biology education lecturers in incorporating problematic socio-scientific issues into their teaching.
**Method:** we conducted a quantitative descriptive survey with 42 lecturers from various universities to analyze their frequency of SSI utilization, the sorts of concerns addressed, the instructional tactics implemented, and the perceived obstacles.
**Results:** research indicates that while educators acknowledge the pedagogical significance of SSI, only a small fraction consistently incorporates it into their teaching. Environmental themes prevail in classroom discussions, whereas more intricate and ethically problematic subjects, such as genetic engineering and bioethics, are infrequently explored. Principal problems encompass student preparedness, resource constraints, and cultural sensitivities. Notwithstanding these obstacles, educators emphasize the importance of SSI in developing essential 21st- century competencies.
**Conclusions:** this study concludes that effective integration of Socio-Scientific Issues (SSI) in biology education in Indonesia requires structured training programs, collaborative support, and alignment of policies across educational institutions. These findings suggest that addressing the challenges identified in the study can significantly enhance the understanding and teaching practices of biology lecturers, fostering a more SSI-inclusive approach in higher education.

**Keywords:** Socio-Scientific Issues; Biology Education; Controversial Topics; Pedagogical Strategies; Science Curriculum Reform.

## RESUMEN

**Introducción:** la incorporación de Problemas Socio-Científicos (SSI) en la educación científica se ha convertido en una estrategia pedagógica efectiva para mejorar el pensamiento crítico, el razonamiento ético y la alfabetización científica de los estudiantes. En Indonesia, caracterizada por la diversidad cultural y las limitaciones curriculares, hay una comprensión limitada de cómo los profesores de biología abordan los temas

científicos controvertidos en el aula. A pesar del creciente enfoque global en la pedagogía basada en SSI, su aplicación en la educación superior indonesia sigue siendo insuficientemente examinada. Este estudio examina la comprensión, los comportamientos y los obstáculos que enfrentan los docentes de educación en biología al incorporar problemas socio-científicos problemáticos en su enseñanza.
**Método:** realizamos una encuesta descriptiva cuantitativa con 42 docentes de diversas universidades para analizar la frecuencia de utilización de SSI, los tipos de preocupaciones abordadas, las tácticas de instrucción implementadas y los obstáculos percibidos.
**Resultados:** la investigación indica que, aunque los educadores reconocen la importancia pedagógica de los SSI, solo una pequeña fracción los incorpora de manera consistente en su enseñanza. Los temas ambientales predominan en las discusiones en clase, mientras que los temas más complejos y éticamente problemáticos, como la ingeniería genética y la bioética, son explorados con poca frecuencia. Los principales problemas abarcan la preparación de los estudiantes, las limitaciones de recursos y las sensibilidades culturales. A pesar de estos obstáculos, los educadores enfatizan la importancia de la SSI en el desarrollo de competencias esenciales del siglo XXI.
**Conclusiones**: la investigación destaca la importancia de la formación organizada, la asistencia cooperativa y la coherencia de políticas para avanzar en la integración de SSI en la biología y otros campos en la educación superior indonesia.

**Palabras clave:** Problemas Socio-Científicos; Educación en Biología; Temas Controversiales; Estrategias Pedagógicas; Reforma del Currículo de Ciencias.

## INTRODUCTION

In the 21st century, science education is increasingly recognized not only as a means to impart scientific knowledge but also as a tool for fostering critical thinking, ethical reasoning, and civic engagement among students.[1,2,3,4] One significant framework that has emerged is the integration of Socio-Scientific Issues (SSI), which are socially relevant, contentious, and scientifically grounded matters such as climate change, genetic engineering, and vaccination. These issues require students to evaluate evidence, deliberate, and consider the ethical and societal implications of scientific knowledge.[5,6,7]

Recent global trends highlight the growing importance of SSI-based pedagogy in enhancing scientific literacy, fostering interdisciplinary learning, and preparing students to tackle complex global challenges.[7,8,9,10,11,12] Studies show that when students engage with contentious topics, they not only deepen their understanding of scientific principles but also develop the skills needed for informed decision-making as responsible citizens.[13,14,15] Furthermore, SSI-based instruction aligns with modern educational objectives, including sustainable development, critical pedagogy, and democratic engagement.[16,17,18,19]

In Southeast Asia, particularly in Indonesia, the conversation around SSI is intensifying, driven by concerns such as environmental degradation, climatic vulnerability, and biotechnology advancements. Issues like deforestation, genetically modified organisms (GMOs), vaccine hesitancy, and religious opposition to medical operations present significant challenges for Indonesian society.[20, 21] These challenges make the integration of SSI into science curricula crucial, yet SSI-based education remains underutilized in Indonesian higher education. Despite national curricula emphasizing critical thinking and scientific literacy, the implementation of SSI in university-level classrooms is inconsistent.

Biology education in Indonesia presents a paradox: modern pedagogical approaches are often hindered by traditional practices and a lack of resources. While biology courses provide an ideal platform for addressing ethically and socially relevant scientific issues [22,23 24] instructors often avoid or only minimally engage with contentious topics due to concerns about backlash, lack of training, and institutional resistance.[25,26,27] In contrast, younger lecturers or those in more conservative institutional settings often refrain from such conversations due to concerns about backlash or misinterpretation.[28]

This scenario reveals a substantial deficiency in the literature concerning science education in Indonesia. Although SSI research has thrived in Western contexts, there is a paucity of studies examining how science educators in non-Western, culturally diverse, and religiously plural societies manage the pedagogical risks and opportunities associated with controversial discussions.[29,30] Indonesia, the largest Muslim-majority nation globally, characterized by its diverse ethnic and cultural landscape, poses distinct problems and potential for the implementation of SSI.[31,32] The incorporation of contentious subjects in biology courses requires careful navigation to honor students' varied perspectives and socio-cultural norms, while promoting critical inquiry and evidence-based reasoning.

Consequently, it is imperative to comprehend how Indonesian biology lecturers interpret, negotiate, and apply SSI, especially those that are ethically or culturally sensitive. While prior studies have recorded lecturers'

overall perceptions of SSI-based education [8,33] there is still a significant gap in understanding the specific pedagogical strategies and challenges faced by educators in this context.

## METHOD

### Reseach Design

This study employs a descriptive quantitative survey methodology to investigate the perceptions and teaching methods of biology lecturers regarding controversial Socio-Scientific Issues (SSIs) in Indonesian university classrooms. The aim is to describe trends, frequencies, and patterns in lecturers' awareness and application of SSI-based teaching. This design facilitates the collection of standardized data, allowing for a systematic assessment of how SSI is integrated into biology teaching across diverse educational settings.

The use of structured surveys ensures consistency in data collection, enabling the comparison of data from multiple institutions. This approach provides valuable insights into both shared challenges and institutional differences in SSI implementation. Furthermore, the descriptive nature of the design allows for the identification of contextual obstacles, educational approaches, and the types of support required to enhance SSI-based learning. This methodology ensures factual clarity and provides a detailed understanding of how lecturers navigate the complexities of incorporating SSI into their classrooms.

### Participants

This study involved biology education teachers from diverse higher education institutions throughout Indonesia. A total of 42 lecturers were chosen through purposive sampling to guarantee that respondents possessed pertinent experience and exposure to Socio-Scientific Issues (SSI) in their instruction. Data were collected from these lecturers March and August 2024. Participants were required to be currently teaching undergraduate biology courses and possess a basic understanding of the idea of SSI. The sample encompassed a variety of institutions, including Universitas Negeri Makassar, Tadulako University, Universitas Muhammadiyah Bone, and IAIN Ternate, thereby illustrating geographical and institutional diversity. Demographic data were gathered to document participants' academic positions, including Assistant Professor and Associate Professor, with their years of teaching experience, spanning from early-career to senior educators. This demographic distribution facilitated the examination of how varying levels of expertise and academic roles may affect the frequency, confidence, and techniques utilized in addressing contentious SSIs in the classroom.The study involved biology education lecturers from nine universities in Indonesia. These included Universitas Negeri Makassar (8 lecturers), Universitas Patompo (6), Tadulako University (5), Universitas Muhammadiyah Bone (4), IAIN Ternate (4), Universitas Negeri Gorontalo (4), IAIN Kendari (3), Universitas Cokroaminoto (3), and Universitas Sulawesi Barat (3). The participants represented a mix of public and Islamic institutions located across eastern Indonesia.

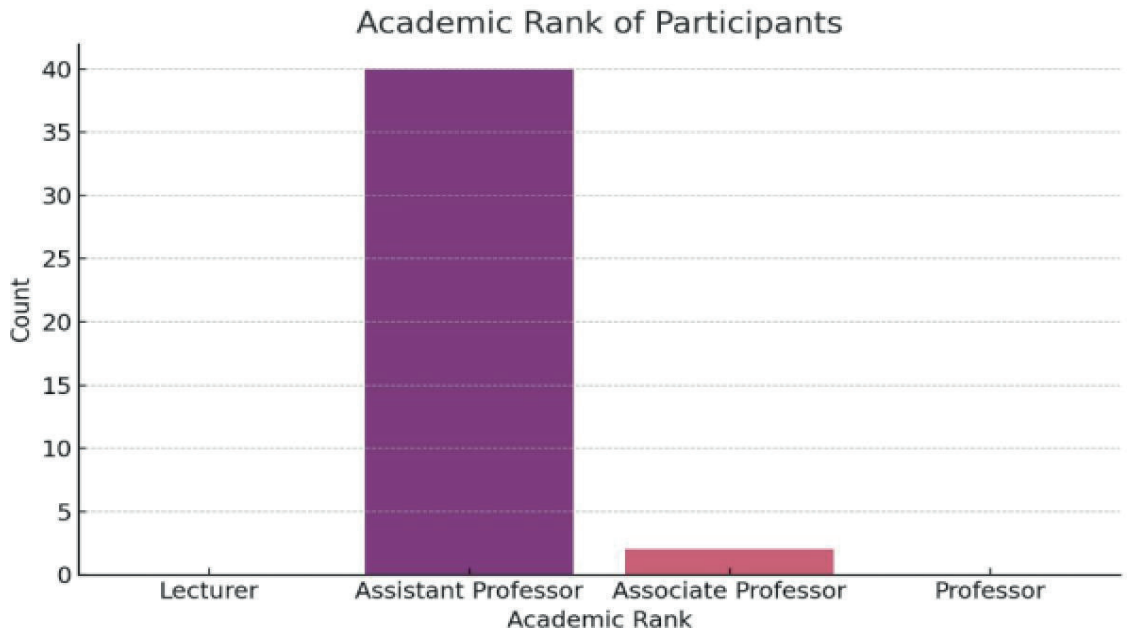


**Figure 1.** Academic Rank of Participants

Figure 1 depicts the academic ranks of the participating lecturers. The majority—40 of 42 participants—were Assistant Professors, whereas only 2 were Associate Professors. No individuals held the ranks of Lecturer

or Professor, signifying a predominance of early- to mid-career academics in the study. This composition is crucial as it indicates that the majority of respondents are at a pivotal phase of professional development, where educational innovations like SSI may be emerging but have not yet been fully institutionalized. Their perspectives and methodologies provide significant insights into the present and future directions of scientific education reform.

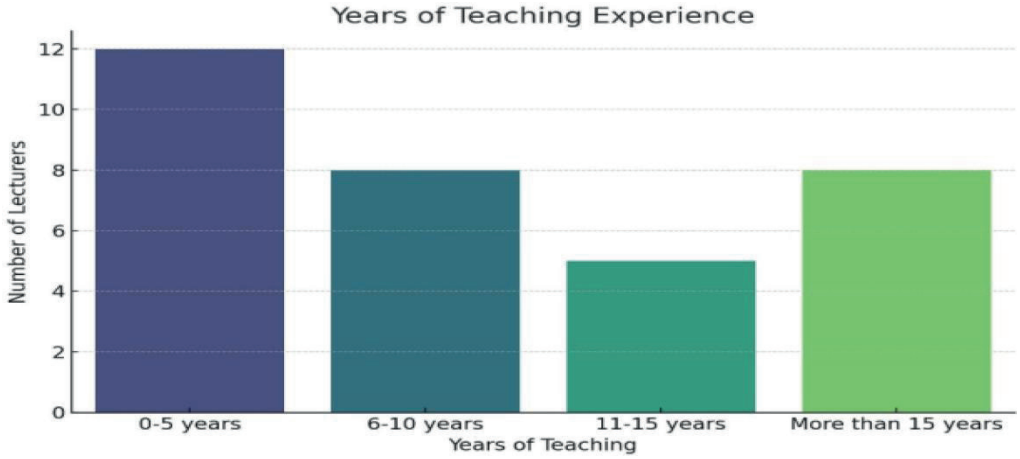


**Figure 2.** Years of Teaching Experience

Figure 2 illustrates the distribution of participants according to their years of teaching experience. The predominant cohort (12 lecturers) have 0–5 years of experience, signifying a substantial presence of early-career educators. This was succeeded by 8 lecturers in the 6–10 and 15+ years categories, and 5 with 11–15 years of expertise. This compilation offers a comprehensive perspective on SSI implementation throughout various career stages. The presence of senior educators (15+ years) indicates that experienced lecturers are involved in current pedagogical transformations, perhaps impacting institutional change and mentoring junior faculty in the integration of contentious SSI topics.

**Instrumentation**

Data were gathered through a structured online questionnaire disseminated via Google Forms, aimed at capturing lecturers' perspectives and instructional techniques about controversial Socio-Scientific Issue (SSI) talks. The questionnaire items were derived from previously verified research on SSI, pedagogical beliefs, and critical thinking in scientific education [6,34] hence assuring reliability and contextual pertinence. The instrument comprised several components: (1) demographic data, (2) awareness of SSI-based pedagogy, (3) frequency and context of controversial SSI integration, (4) categories of issues addressed (e.g., genetic engineering, climate change), (5) challenges and obstacles faced, (6) pedagogical strategies utilized, (7) perceptions of student preparedness and institutional support, and (8) suggestions for enhancing SSI implementation. The questionnaire's design facilitated both closed-ended and Likert-scale responses, permitting descriptive statistical analysis of trends and variations in how biology lecturers address difficult themes in their teaching techniques.

**Data Collection Procedure**

Data collection was performed online via a standardized Google Form to guarantee inittional emails and professional academic networks. The data collection occurred in [Insert Month and Year], providing participants sufficient time

to reply at their convenience. Ethical considerations were meticulously adhered to during the research process. Digital informed consent was acquired at the outset of the questionnaire, guaranteeing that participants comprehended the study's aims and their rights. Participation was wholly voluntary, and no personal identifiers were gathered to maintain respondent anonymity and confidentiality. Respondents were permitted to withdraw or omit any item without repercussions.

**Data Analysis**

The gathered data were examined employing descriptive statistical methods to encapsulate trends and patterns in the responses. Frequency and percentage analyses were conducted on closed-ended items to determine the occurrence of specific responses, while measures of central tendency, such as mean and mode, were computed for Likert-scale items to assess general attitudes and preferences. Microsoft Excel was predominantly utilized for data tabulation and visualization, whilst SPSS (version [insert version]) was applied

for statistical analysis and interpretation. The analysis concentrated on three principal areas: (1) assessing the degree and uniformity of SSI implementation in biology classrooms, (2) elucidating the most commonly addressed contentious socio-scientific issues—such as genetic engineering, climate change, and environmental ethics, and (3) investigating the correlation between lecturers' years of teaching experience and their participation in SSI discussions. These analyses offered an extensive overview of the existing practices, perceived obstacles, and pedagogical dynamics influencing SSI-based instruction in Indonesian higher education.

**Validity and Reliability**

To guarantee the validity and reliability of the study instrument, multiple measures were implemented. Face and content validity were confirmed via expert evaluation by three distinguished academics in scientific education, who assessed the questionnaire for clarity, relevance, and agreement with the research objectives. Their feedback was utilized to amend unclear or repetitive items, guaranteeing the instrument precisely reflected lecturers' perspectives and behaviors concerning problematic Socio-Scientific Issue (SSI) debates. A pilot test was administered using five biology education instructors who were excluded from the primary study. This trial phase facilitated the evaluation of the clarity, sequencing, and suitability of the questionnaire items. Minor modifications were implemented in response to their feedback to improve item clarity. The instrument predominantly employed descriptive items; however, internal consistency was also assessed, and Cronbach's Alpha was computed when relevant to evaluate the reliability of Likert-scale items. These approaches guaranteed conceptual coherence and measurement consistency throughout the study.

## RESULTS

**Lecturer Familiarity with Socio-Scientific Issues (SSI)**

As shown in figure 2, varying degrees of awareness of Socio-Scientific Issues (SSI) were observed among biology education lecturers, particularly across different teaching experience categories.

Instructors with over 15 years of teaching experience reported the highest level of awareness, with more than 85 % indicating familiarity with or involvement in SSI-related ideas. In contrast, over 50 % of lecturers with 0–5 years of experience indicated unfamiliarity with the term. Those with 6–10 and 11–15 years of experience demonstrated moderate levels of awareness, reflecting a gradual increase in familiarity as teaching experience increases.

**Table 1**. Lecturer Familiarity with SSI by Experience

| Years of Teaching | Heard of SSI | Not Heard of SSI | Total |
|---|---|---|---|
| 0-5 years | 4 | 5 | 9 |
| 6-10 years | 8 | 8 | 16 |
| 11-15 years | 5 | 5 | 10 |
| More than 15 years | 6 | 1 | 7 |

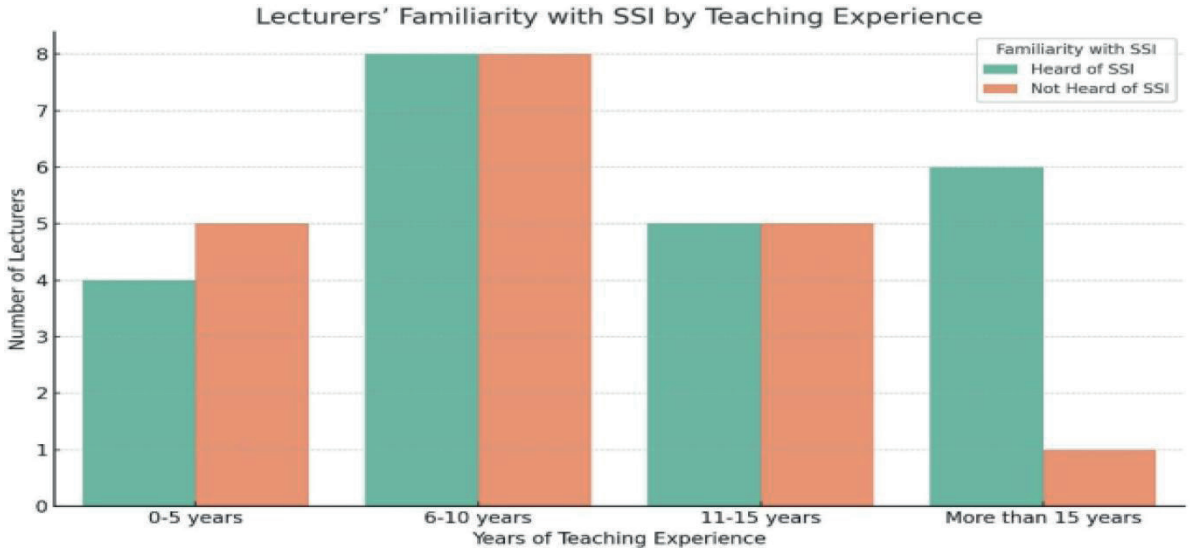


**Figure 3**. Lecturers' Familiarity with SSI by Teaching Experience

Table 1 presents the distribution of biology education lecturers' familiarity with Socio-Scientific Issues (SSI) based on their years of teaching experience. The group with the largest number of participants was those with 6–10 years of teaching experience (n = 16), equally divided between those who reported familiarity with SSI (n = 8) and those who did not (n = 8). In the 11–15 years category, 5 lecturers were familiar with SSI and 5 were not. Among lecturers with more than 15 years of experience, 6 out of 7 reported familiarity. The group with the least experience (0–5 years) had 4 lecturers who reported familiarity and 5 who did not.

Figure 3 depicts the distribution of biology lecturers' familiarity with Socio-Scientific Issues (SSI) based on four categories of teaching experience.

Among lecturers with more than 15 years of experience, 6 out of 7 reported prior exposure to SSI. In contrast, in the 0–5 years category, more respondents were unfamiliar with SSI than familiar. For those with 6–10 and 11–15 years of experience, the levels of familiarity and unfamiliarity were relatively balanced.

*Frequency of SSI-Based Teaching Implementation.*

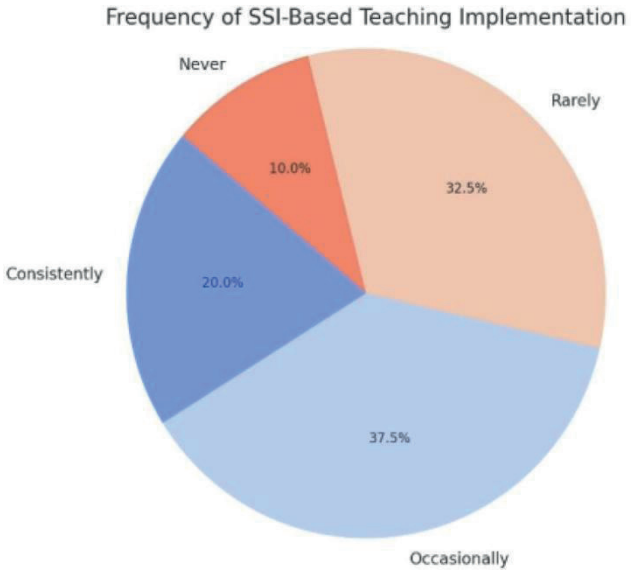


**Figure 4.** Requency of SSI-Based Teaching Implementation

Figure 4 depicts the frequency of SSI-based teaching implementation by Indonesian biology instructors in their courses. The predominant component (37,5 %) comprises individuals who utilize SSI sporadically, indicating that although the methodology is recognized, it is not yet uniformly implemented. A substantial percentage (32,5 %) indicate infrequent usage, while merely 20 % utilize it routinely. Significantly, 10 % of professors had never employed SSI.

*Instructional Contexts of SSI Integration*

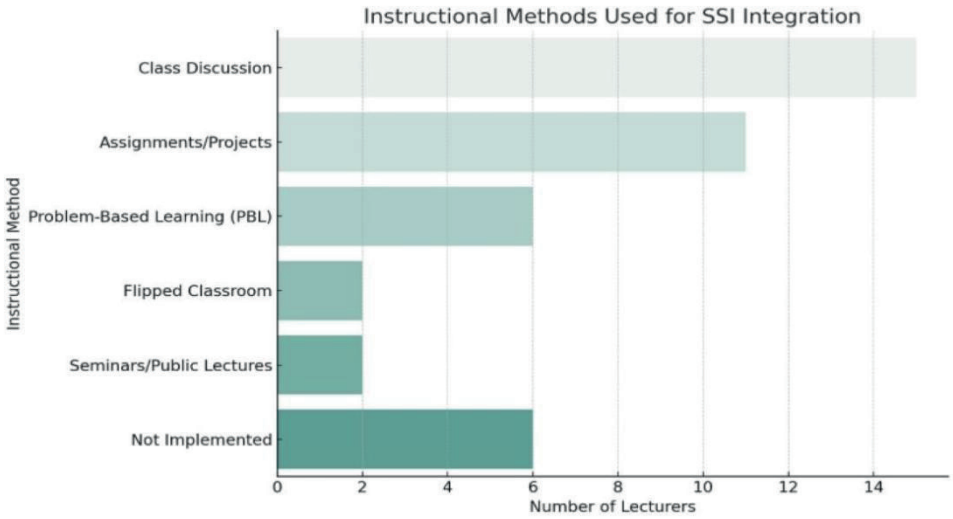


**Figure 5**. Instructional Methods Used for SSI Integration

Figure 5 illustrates the educational scenarios in which biology lecturers include Socio-Scientific Issues (SSI) into their pedagogy. Class talks prevail, with 15 lecturers (35,7 %) employing this approach, indicating a propensity for dialogic interaction. Assignments and projects are strongly associated with 11 responses (26,2 %), indicating a focus on student-driven inquiry. Problem-Based Learning (PBL) was implemented by 6 lecturers (14,3 %), signifying a partial adoption of active learning methodologies. Flipped classes and public lectures were utilized sparingly, with only two instructors employing each method. Interestingly, 6 lecturers reported not implementing SSI at all, signaling barriers or uncertainty around integration strategies.

**Frequency of Controversial Issue Discussions**

The statistics indicate significant diversity in the frequency with which biology lecturers introduce problematic Socio-Scientific Issues (SSIs) in classroom discussions. A majority of respondents (35,7 %) indicated that they occasionally addressed such concerns, whilst 28,6 % acknowledged doing so infrequently. Only 21,4 % indicated that they frequently broached challenging themes, while 14,3 % reported never involving students in such talks. Cross-tabulation with academic rank and years of teaching experience revealed a striking trend: lecturers with over 15 years of experience were markedly more inclined to frequently address problematic themes, indicating a degree of confidence and pedagogical maturity. Conversely, early-career lecturers—especially those with less than 5 years of experience or in the Assistant Professor category—exhibited greater reluctance, evidenced by a higher incidence of infrequent or absent responses.

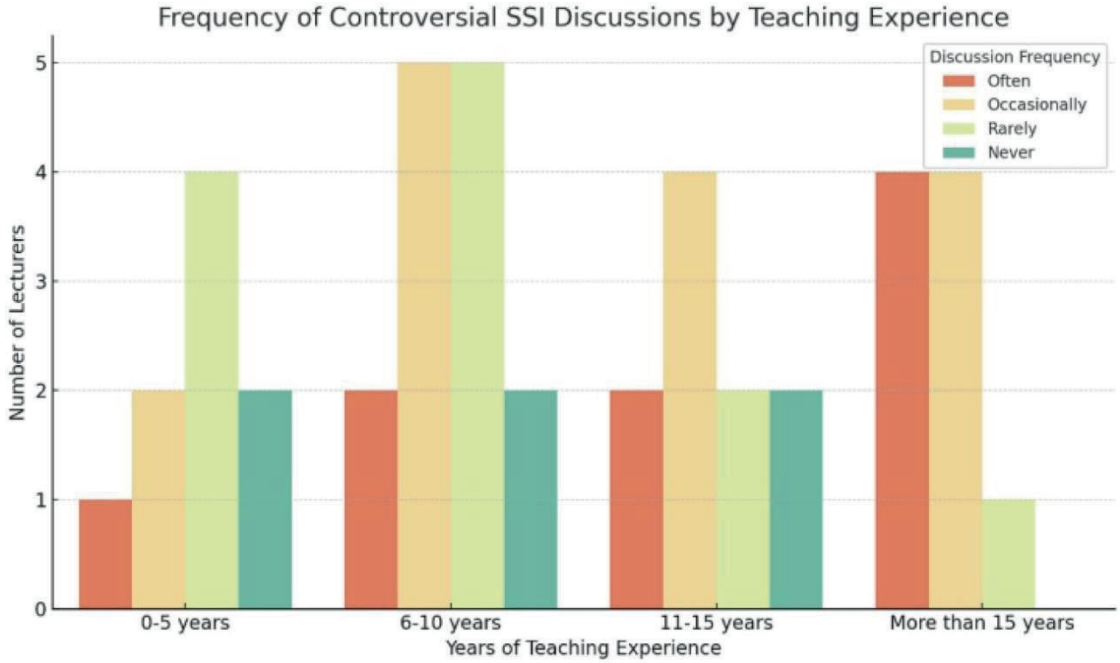


**Figure 6.** Frequency of Controversial SSI Discussions by Teaching Experience

Figure 6 illustrates the frequency with which lecturers of differing teaching experience involve students in discussions on difficult Socio-Scientific Issues (SSIs).

Lecturers with over 15 years of experience are most inclined to routinely address such topics—4 out of 7 indicated doing so "often," while none stated "never." In contrast, lecturers with 0–5 years of experience exhibited reluctance, with the majority indicating "rarely" or "never." Individuals aged 6 to 15 are uniformly represented across all categories, demonstrating moderate engagement.

**Table 2.** Controversial SSI Discussion Frequency

| Discussion Frequency | Total Lecturers |
|---|---|
| Often | 9 |
| Occasionally | 15 |
| Rarely | 12 |
| Never | 6 |

These problems "occasionally," and 28,6 % reported doing so "rarely." A minority (21,4 %) participated

"often," while 14,3 % "never" engaged in discussions on such themes. These results indicate that, although the significance of SSIs is acknowledged, their implementation in classrooms is inconsistent. The hesitance may arise from cultural sensitivity, insufficient training, or perceived hazards in classroom management

*Types of Socio-Scientific Issues Discussed*

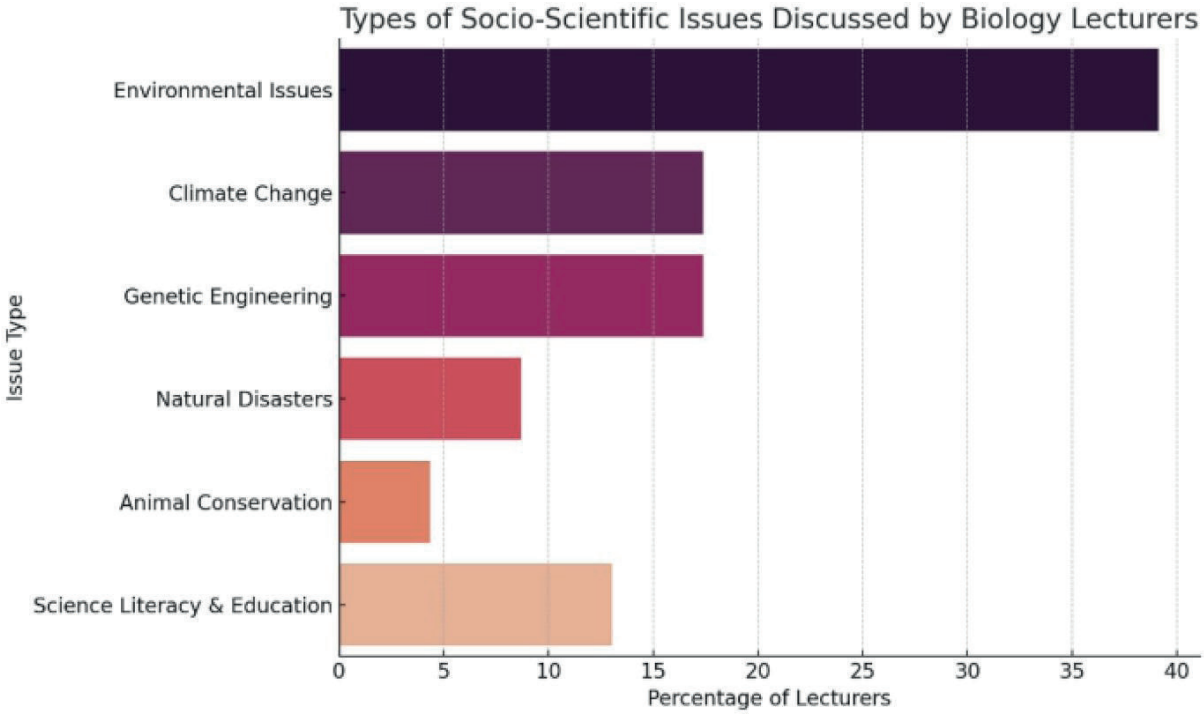


**Figure 7.** Types of Socio-Scientific Issues Discussed by Biology Lecturers

Figure 7 illustrates the distribution of socio-scientific issues (SSIs) most commonly addressed by biology instructors.

Environmental challenges constitute 39,13 %, encompassing pollution, waste, and ecological degradation, underscoring their critical significance in Indonesia's socio-ecological landscape. Climate change and genetic engineering each account for 17,39 %, reflecting an increasing awareness of global and biotechnological issues. Scientific literacy and educational issues (13,05 %) emphasize initiatives to connect conceptual comprehension with societal significance. Topics that are less commonly discussed encompass natural disasters (8,7 %) and animal conservation (4,35 %).

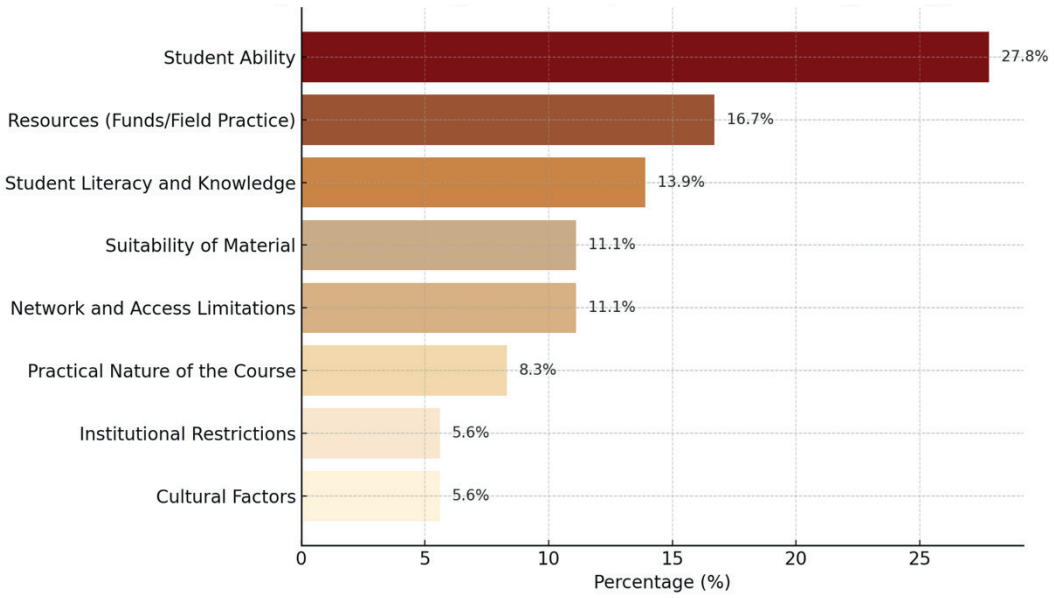


**Figure 8**. Challenges Faced in SSI Implementation

**Challenges Faced in SSI Implementation**

Figure 8 delineates the primary problems encountered by biology lecturers in the implementation of Socio-Scientific Issue (SSI)-based instruction. The most prominent obstacle is student ability (27,8 %), underscoring deficiencies in students' analytical and argumentative skills necessary for addressing intricate, real-world problems.

Resource constraints—such as insufficient financing or limited field practice opportunities—rank second (16,7 %), followed by inadequate student literacy and knowledge (13,9 %). Additional significant obstacles encompass the discordance between content and pertinent issues, inadequate digital infrastructure, and the culturally sensitive characteristics of specific subjects.

**Table 3.** Challenges in SSI Implementation

| Challenge | Percentage |
|---|---|
| Student Ability | 27,8 |
| Resources (Funds/Field Practice) | 16,7 |
| Student Literacy and Knowledge | 13,9 |
| Suitability of Material | 11,1 |
| Network and Access Limitations | 11,1 |
| Practical Nature of the Course | 8,3 |
| Institutional Restrictions | 5,6 |
| Cultural Factors | 5,6 |

Table 3 enumerates the most commonly cited problems in the integration of SSI- based pedagogy. Over a quarter of respondents recognized student ability, highlighting worries regarding learners' preparedness to critically interact with contentious material. Inadequate teaching resources and practical limitations indicate that numerous institutions may lack the necessary infrastructure or support structures for effective SSI implementation. Challenges pertaining to cultural appropriateness, institutional constraints, and access to networks or digital resources further complicate implementation.

**Relevant Biology Topics for SSI Integration**

The results indicate that educators consider specific biology subjects, particularly ecology and environmental issues, as very pertinent for the integration of Socio- Scientific Issues (SSI), with a prevalence of 38,1 %. Subsequent subjects encompass natural catastrophes, air, and evolution (21,2 %), with health-related concerns, including diet (13,6 %). Bioethics (11,0 %) and microbiology (10,2 %) were regarded as significantly pertinent, particularly for fostering ethical reasoning and societal discourse. A minority (5,9 %) chose genetics, notwithstanding its significant presence in current scientific discussions worldwide.

Analysis by institution and academic rank revealed that senior lecturers and those affiliated with research-intensive universities reported a wider array of SSI-relevant topics, presumably due to increased exposure to interdisciplinary curriculum approaches. Conversely, early- career instructors often concentrated on conventional environmental and health topics, likely due to curriculum limitations or restricted pedagogical freedom.

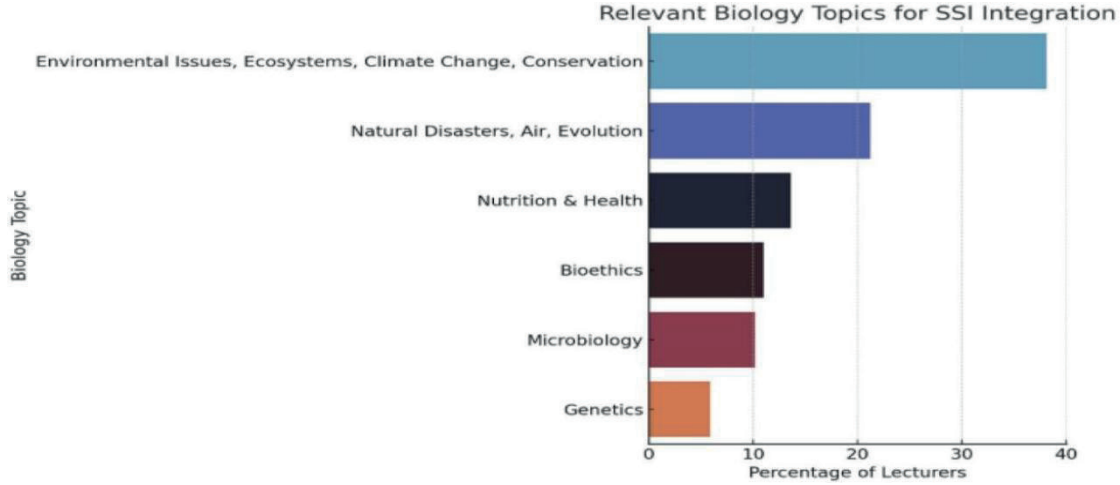


**Figure 9**. Relevant Biology Topics for SSI Integration

Figure 9 illustrates the biological areas deemed most pertinent by educators for the integration of Socio-Scientific Issues (SSI). Subjects concerning natural disasters and evolution (21,2 %) garnered significant attention, particularly in areas susceptible to environmental disturbances. Nutrition and health placed third at 13,6 %, indicating an increasing interest in public health education. Simultaneously, bioethics (11,0 %) and microbiology (10,2 %) received moderate recognition, indicating a valuation of ethical examination and the significance of microbes in the science-society dialogue. Genetics, while fundamental, is still inadequately employed in SSI situations.

*Key Skills Promoted by SSI*

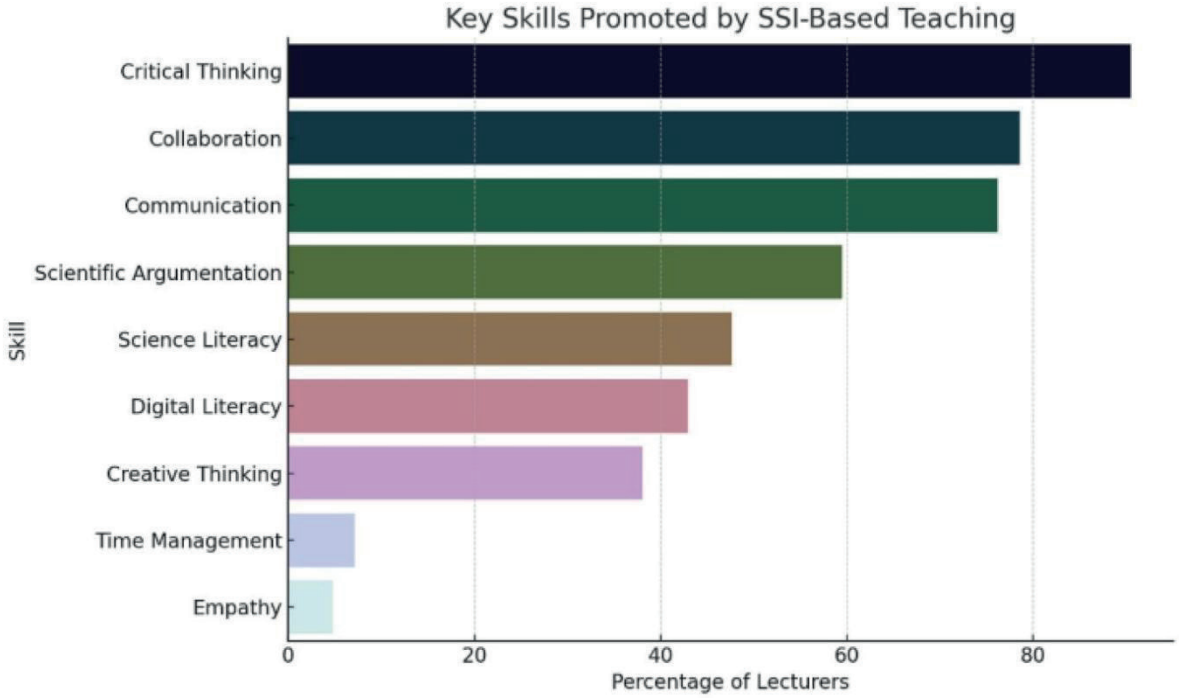


**Figure 10.** Key Skills Promoted by SSI-Based Teaching

Figure 10 illustrates biology instructors' perspectives of the fundamental abilities developed through the integration of Socio-Scientific Issues (SSI). Critical thinking predominates at 90,5 %, underscoring its essential function in the analysis of intricate, real-world issues. Collaboration (78,6 %) and communication (76,2 %) closely trail, underscoring the significance of teamwork and dialogic learning. Scientific argumentation (59,5 %) underscores the need of evidence-based reasoning, whilst science literacy (47,6 %) and digital literacy (42,9 %) highlight the necessity for both conceptual and technological proficiencies. While creative thinking (38,1 %) is recognized, time management (7,1 %) and empathy (4,8 %) are notably underrepresented, indicating that these soft skills are deprioritized in SSI-based pedagogical planning.

## DISCUSSION

### Variability in SSI Awareness and Engagement

with the idea that pedagogical confidence and professional autonomy typically enhance over time, allowing more seasoned instructors to implement novel and nuanced teaching methods, such as SSI-based instruction.

These data suggest that professional longevity is associated with heightened engagement in modern instructional methods, such as SSI. The segmented bar chart corroborates this tendency, indicating that more seasoned lecturers are better equipped to use SSI pedagogy, likely due to accrued training opportunities and exposure to interdisciplinary teaching methodologies. This trend may guide focused capacity-building initiatives for novice educators. This pattern underscores a possible deficiency in pedagogical training that novice lecturers may encounter upon entering higher education. The data indicate that knowledge with SSI pedagogy correlates positively with teaching experience, likely due to increased exposure to professional development and curriculum reform activities over time. Conversely, early-career lecturers (0–5 years) had the lowest levels of familiarity and implementation, potentially indicative of restricted exposure to interdisciplinary teaching during their training or reluctance arising from institutional and cultural limitations.

This pattern corroborates the findings of [6] who noted that educators with greater teaching experience are more predisposed to involve students in authentic scientific discussions and ethical dilemmas. The present

study corroborates this pattern within a non-Western environment, highlighting the significance of experiential knowledge in influencing educational decisions. It also underscores a significant deficiency in teacher preparation programs, where SSI pedagogy is little represented. In the absence of specialized training and assistance, early-career lecturers may find it challenging to manage conversations on sensitive issues, leading to lost chances for fostering students' critical thinking and social awareness. Mitigating this heterogeneity necessitates not only the enhancement of individual competencies but also the establishment of institutional frameworks that promote and standardize the integration of SSI across all levels of teaching experience.

**Underutilization of Controversial SSI Topics**

This study highlights a considerable disparity between theoretical support and practical implementation of Socio-Scientific Issues (SSI) in the classroom among Indonesian biology lecturers, despite widespread acknowledgment of their educational benefits in fostering critical thinking, ethical reasoning, and civic involvement. While most participants recognized the significance of SSI, only a limited number consistently incorporated contentious topics—such as genetic engineering, evolution, or vaccination—into their instruction. This underutilization indicates a disparity between lecturers' perceptions of value and their sense of empowerment or comfort in implementation.

A significant contributing aspect is cultural sensitivity. In Indonesia's multifaceted and religiously varied society, subjects that contest established moral, religious, or cultural norms may be perceived as perilous or unsuitable for candid classroom discourse.[35,36] For example, discourse on evolution or stem cell research may contradict students' beliefs, leading instructors to eschew these topics entirely to preserve classroom peace. Moreover, institutional reluctance—evidenced by inflexible curricula, insufficient policy backing, or lack of professional incentives— further dissuades instructors from straying from traditional material delivery methods. This distribution reveals a significant disparity between awareness and implementation, possibly attributable to obstacles such as insufficient training, institutional backing, or educational resources. These findings highlight the necessity for systematic interventions to facilitate the consistent and substantive incorporation of SSI in biology instruction.

This gap reflects difficulties seen in other culturally conservative environments, when the apprehension of offending students or inciting institutional displeasure hinders the incorporation of socially problematic material. Consequently, SSI conversations often concentrate on "safe" subjects like as environmental pollution or climate change, while ethically contentious or politically problematic matters remain insufficiently examined. Addressing this disparity necessitates intentional actions to cultivate inclusive educational environments, bolstered by institutional rules that promote open dialogue while honoring cultural norms.

**Preferred Pedagogical Approaches**

The findings reveal that class discussions are the predominant strategy employed by Indonesian biology lecturers for intgrating Socio-Scientific Issues (SSI), succeeded by assignments and projects. Conversely, more organized and inquiry-based methodologies—such as Problem-Based Learning (PBL), flipped classrooms, or public seminars—are significantly underutilized. This inclination towards class discussions may arise from their adaptability, low resource demands, and established presence in conventional pedagogical practices. While talks are beneficial for engaging with challenging themes, they may not always offer the necessary depth of inquiry or collaborative discovery to adequately cultivate students' analytical and ethical reasoning abilities. These patterns indicate that although interactive methods are preferred, advanced or alternative pedagogies such as flipped learning are still neglected.

The restricted application of PBL and seminars indicates a necessity for specialized pedagogical training to enhance lecturers' instructional methodologies for SSI integration. Project-Based Learning (PBL) provides a comprehensive framework for navigating intricate, real-world issues that necessitate multidisciplinary analysis and collaborative decision-making—competencies closely matched with the objectives of Socio-Scientific Issues (SSI) pedagogy. Public lectures or seminars can offer genuine venues for engaging with varied perspectives, particularly when featuring experts, community representatives, or case-based simulations.

These findings highlight the necessity of creating professional development programs that enhance understanding of SSI content while also exemplifying novel educational strategies for tackling contentious scientific issues. Teacher education course design should prioritize scaffolded practice in promoting inquiry-based learning, ethical discussions, and case analysis. This will equip educators to advance from superficial involvement to a more profound, student-centered incorporation of SSI in science instruction.

**Environmental Issues as a Dominant Theme**

The results indicate that environmental concerns—specifically pollution, climate change, and ecosystem degradation—are the predominant Socio-Scientific Issues (SSI) addressed by Indonesian biology lecturers. This significance is due to their excellent congruence with national and global curriculum interests, together with

their immediacy and visibility in students' daily lives. Indonesia's susceptibility to environmental disasters such as deforestation, flooding, and air pollution renders these subjects particularly pertinent for contextual learning. Moreover, environmental issues are typically regarded as "safe" topics that are unlikely to incite cultural or religious disputes, enabling educators to present them without apprehension of conflict or institutional opposition.

Conversely, ethically significant subjects like genetic engineering, bioethics, and evolution are still little explored. These concerns frequently connect with entrenched moral, religious, or philosophical convictions, complicating their navigation in educational environments. Instructors may perceive themselves as insufficiently equipped to facilitate such dialogues or may lack access to impartial, well-structured instructional resources. Institutional constraints, such as inflexible curricula and performance-oriented evaluation systems, may additionally inhibit the examination of contentious yet educationally valuable material.

This disparity constrains the breadth of students' ethical thinking and scientific investigation. Although environmental issues are crucial, overlooking other aspects of science and society limits learners' understanding of the wider array of scientific challenges. To resolve this issue, teacher preparation and curriculum development must ensure comprehensive covering of SSI domains, providing educators with both material expertise and pedagogical resources to adeptly tackle more contentious or intricate subjects.

**Barriers to SSI Implementation**

This study found two primary obstacles to the effective application of Socio- Scientific Issue (SSI)-based instruction in Indonesian biology classrooms: student preparedness and resource limitations. Instructors voiced apprehension regarding students' inadequate critical thinking abilities, deficient scientific literacy, and restricted prior knowledge—elements that hinder their capacity to participate in substantive discussions on intricate, contentious subjects. A multitude of students encounter difficulties in assessing arguments, integrating information across several fields, or adopting evidence-based ethical stances. This corresponds with international research, like that of [34] who highlighted the crucial influence of student readiness on the effectiveness of SSI instruction in many educational settings.

Moreover, resource-related limitations, including insufficient teaching materials, financing, laboratory access, and internet connectivity, pose structural difficulties that deter lecturers from implementing SSI methodologies. These constraints impede the implementation of active learning methodologies such as project-based learning or case study analysis, which are fundamental to SSI pedagogy. In under-resourced institutions, educators may prioritize content dissemination over student-centered, inquiry-based learning due to temporal and logistical limitations. These findings highlight the necessity for specialized professional development to equip educators with the techniques and confidence required to properly address difficult scientific problems.

The relationship between student preparedness and resource limitations illustrates wider systemic challenges in science education, especially in developing or decentralized environments. Overcoming these obstacles necessitates a dual strategy: imparting essential cognitive skills to kids via early curricular interventions, and ensuring instructors receive continuous access to SSI-specific training, resources, and institutional support. In the absence of such expenditures, the capacity of SSI to revolutionize science education into a more pertinent, ethical, and socially involved endeavor would remain unfulfilled.

**Skill Development through SSI**

This study's findings confirm that biology lecturers regard critical thinking, communication, and teamwork as the key abilities fostered by Socio-Scientific Issue (SSI)-based instruction.

These skilss re essential for addressing intricate, real- world issues that necessitate students to evaluate facts, contemplate varied viewpoints, and express well-reasoned arguments. SSI pedagogy inherently promotes dialogic learning and collaborative problem-solving, rendering it an effective means for developing these advanced skills. This closely corresponds with the 21st-century skills framework articulated by [37] which underscores critical thinking, communication, teamwork, and creativity as vital for equipping learners to excel in a knowledge-driven society.

By involving students in ethically complex and socially pertinent scientific matters, SSI fosters possibilities for significant discussion, debate, and contemplation. In this study, lecturers notably esteemed the cultivation of thinking skills, teamwork capabilities, and oral communication—abilities frequently neglected in conventional scientific classrooms that emphasize rote memorization and material mastery. Nonetheless, the inadequate ratings of skills such as time management and empathy suggest that the affective and organizational aspects of learning have not been adequately included into SSI education.

These results highlight the necessity to expand on deliberate skill development. Curriculum designers and teacher educators explicitly embed 21st-century skill outcomes into SSI-based modules, assessments, and training. This approach guarantees that students acquire knowledge of science in society while also developing the transversal abilities necessary for responsible and effective contributions to that society.

## CONCLUSION

This study examined the opinions and teaching methods of Indonesian biology lecturers regarding the integration of controversial Socio-Scientific Issues (SSI) in university-level scientific education. As science classrooms increasingly function as venues for cultivating critical, ethical, and civic abilities, comprehending how educators manage SSI—especially in culturally varied settings such as Indonesia—has emerged as a vital field of investigation.

The results indicate considerable heterogeneity in SSI understanding and execution, with more seasoned lecturers demonstrating enhanced familiarity and confidence in addressing contentious subjects. Nonetheless, SSI-based instruction is predominantly underutilized, primarily owing to student preparedness issues, insufficient educational resources, and cultural or institutional reluctance. Environmental issues surfaced as the predominant topic of discussion, although ethically intricate themes like genetic engineering and bioethics were frequently circumvented. Class discussions were the favored instructional method, although more structured approaches such as problem-based learning or public seminars were infrequently utilized. Instructors emphatically asserted that the incorporation of SSI fosters the enhancement of critical thinking, communication, and collaboration—fundamental competencies linked with 21st-century educational objectives. However, effective implementation is obstructed by inadequate training, absence of interdisciplinary collaboration, and restricted institutional support.

These discoveries highlight the necessity for systematic improvements in teacher training programs, curriculum development, and educational policy. Future study may investigate the long-term effects of SSI-based training on student outcomes and conduct institutional case studies on effective integration models.

By overcoming existing obstacles and enhancing support systems, SSI pedagogy can be broadened not only within biology but throughout the whole educational framework, fostering a more socially responsive and ethically informed scientific education in Indonesia and beyond.

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## CONFLICT OF INTEREST

There is no conflict of interest.

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