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Students' Perceptions of Socio-Scientific Issues in Biology Education: A Case Study in Indonesia

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Abstract: Understanding students' perceptions of socio-scientific issues (SSI), particularly in the context of biology, is essential for developing effective teaching strategies. This study analyzes students' perceptions of SSI in biology, involving 360 participants from 10th- and 11th-grade classes at a high school in Majalengka, West Java, Indonesia. The participants, aged 16 to 17 years, were equally divided between the two grade levels. Data were collected using a 24-item survey questionnaire based on a five-point Likert scale. The results show an overall mean perception score of 3.31, indicating that students generally hold a neutral perception of SSI in biology. A weak correlation was observed between students' overall perceptions and SSI in biology, with a p-value of 0.08 and an r-value of 0.02. Further analysis revealed minor differences in perceptions based on grade level and gender, with 10th-grade students scoring an average of 3.30 and 11th-grade students scoring 3.32. Male students averaged 3.28, while female students averaged 3.34. These findings suggest that although students exhibit neutral perceptions of SSI in biology, many struggle to connect biological concepts to real-life contexts. This highlights the need for further research to identify factors influencing students' perceptions and to explore alternative learning models for improving understanding and engagement with SSI in biology.

INTRODUCTION

Over the last two decades, research on biology learning in the context of socio-scientific issues (SSI) has proven effective in promoting scientific literacy (Ke et al, 2021). This growing interest has captured the attention of researchers, resulting in numerous studies exploring the integration of SSIs into biology education in schools (Ke et al, 2021; Owens et al., 2021; Fuentes & Entezari, 2020; Zidny & Eilks, 2020; Zowada et al, 2018). These investigations encompass a wide range of topics, aiming to help students contextualize scientific knowledge, deepen their understanding of the nature of science (NoS), shape their perceptions, foster multi-perspective reasoning and argumentation, and encourage moral and ethical reflection on scientific scenarios within societal contexts (Archila et al., 2023; Marandino et al., 2023; Richardson & Lacroix, 2021; Subiantoro & Treagust, 2021). These studies highlight key aspects of implementing SSIs in science learning, positioning them as a context for achieving scientific literacy and fostering

the practice of citizenship education within science education (Richardson & Lacroix, 2021; Subiantoro & Treagust, 2021; Zidny & Eilks, 2020; Zowada et al, 2018). The goal of socio-scientific learning is to foster students' active participation in developing argumentation skills, the ability to differentiate science from nonscience issues, and the recognition of reliable evidence and data (Richardson & Lacroix, 2021; Subiantoro & Treagust, 2021; Zidny & Eilks, 2020; Zowada et al, 2018). When designing SSI experiences, it is particularly important to select issues that are relevant and compelling to students (Guevara-Herrero, 2024; Ke et al., 2023; Newton & Zeidler, 2020). SSI instruction includes confronting students with personally meaningful contentious issues and helping them to develop and contemplate multiple sophisticated viewpoints while weighing scientific evidence (Sanchez et al., 2024; Ke et al., 2023; Türk & Çam, 2024;). However, it often involves controversial issues, with examples of these issues could include genetic technology or air pollution, and integrates education on risk analysis, providing opportunities for students to engage with these issues.

Regarding the context of SSI, it is important to know how students generally perceive SSI. In order to do so, we must first discuss what perception means in general and its relations to SSIs (Wiyarsi et al., 2023; Subiantoro & Treagust, 2021). We will also be reviewing previous research on both perception and SSIs. In general, perception is about becoming aware of something through the use of one's senses. To start with, SSI are complex, ill-defined societal issues that have a basis in science such as climate change (Mejía-Cáceres et al., 2023; Sanchez et al., 2024; ; Ke et al, 2021). SSI-based instruction requires students to not only consider the science dimension, but also the social ramifications of the issue in order to develop positions or solutions around the issue (Sadler et al, 2019). They are usually controversial in nature but have the added element of requiring a degree of moral reasoning or the evaluation of ethical concerns in the process of arriving at decisions regarding possible resolution of those issues (Ben-Horin et al., 2023; Estigarribia et al., 2022; Marandino et al., 2023; Zidny & Eilks, 2020; Zeidler & Nichols, 2009). As students interact more and more with the society of which they are a part of, they will eventually be exposed to various socio-scientific issues, either as direct observer or through information they received during their social interactions (Mang et al., 2023; Fuentes & Entezari, 2020). Thus, we can generally assume that students have already develop their own perception towards various SSI that they might encounter.

When it comes to discussing SSI, there is indeed the obvious aspect of science involved (Owens et al., 2021). In this case, socio-scientific issues related to the environment becomes the main focus of this paper. This of course falls within the discipline of biology (Barry et al, 2023; Kaya & Akdinez, 2004; Subiantoro, 2021). While students should generally be aware of socio-scientific issues related to the environment (Kang & Tolppanen, 2024), their perception might come in varying degrees and is influenced by several factors. For example, some studies stated that science or biology teaching remains unpopular among the students and is generally perceived as not being very relevant (Fuentes & Entezari, 2020; Owens et al., 2021). This can be seen clearly for the physical sciences (Osborne, 2001; Holbrook & Rannikmae, 2007; Hofstein, Eilks & Bybee, 2011). From this, we can infer that while student might be aware of the socio-scientific issues in their environment (Kang & Tolppanen, 2024), they might perceive it as not relevant to their lives (Wiyarsi et al., 2023; Subiantoro & Treagust, 2021).. There is also a concern related to SSI, being that science teaching still neglects

the societal dimension of science teaching to a large degree, only rarely orients itself towards prescribed general educational objectives, and still basically ignores the interests of the vast majority of students who will never have careers in Chemistry or Physics (Bybee, 1987; Elmose & Roth, 2005; Holbrook & Rannikmae, 2007; Marks & Eilks, 2009; Hofstein, Eilks & Bybee, 2011). What this means is that while they might have the scientific knowledge, it is not presented in a way that contextualize said knowledge to the social aspect that constitutes many scientific phenomena (Wahyuni et al., 2018; Yuliyanti et al., 2019; Taber et al., 2021; Larasati et al., 2021; Melisa, 2021; Forgione et al., 2023). It is also important for the science education field to promote educative experiences where people contemplate the beliefs, interests, and feelings of others impacted by environmental SSI and form an intrinsic connection with nature, in the sense that nature should be afforded similar intrinsic value and justice that is extended to people (Herman, Zeidler, & Newton, 2020). This raises the importance of studying student's perception towards SSIs, which in this case, related to environmental issues in biology education (Wahyuni et al., 2018; Yuliyanti et al., 2019; Taber et al., 2021; Larasati et al., 2021; Melisa, 2021; Forgione et al., 2023).

When it comes to discussing SSI, by observing the material of environmental pollution directly reveals its presence in the immediate surroundings. The reason behind the topic of environmental pollution being chosen in this instance is because of the immediate nature of this issue to students' in this particular study (Kang & Tolppanen, 2024). This is evident through various natural disasters such as floods, landslides, air pollution, contaminated water, and more, occurring in the region. Human involvement plays a significant role in these disasters due to a lack of appreciation for the values of environmental wisdom (Fuentes & Entezari, 2020; Owens et al., 2021)., knowledge that should ideally be imparted through biology education in senior high schools (Wahyuni et al., 2018; Yuliyanti et al., 2019; Larasati et al., 2021; Melisa, 2021). Recognizing the importance of this, it becomes crucial for students to delve into the study and comprehension of the factors and repercussions of environmental pollution prevalent in their surroundings (Wahyuni et al., 2018; Yuliyanti et al., 2019; Larasati et al., 2021; Melisa, 2021). Nevertheless, imparting understanding to students regarding the causes, impacts, and prevention of environmental pollution is no simple task. Effective methods or approaches are required to convey explanations on this matter to students (Wahyuni et al., 2018; Yuliyanti et al., 2019; Larasati et al., 2021; Melisa, 2021). Utilizing the socio-scientific approach in science biology learning, especially in the context of environmental pollution (Mejía-Cáceres et al., 2023; Sanchez et al., 2024; ; Ke et al., 2021), provides students with a hands-on experience (Mang et al., 2023). This involvement allows them to directly observe, analyze, and evaluate the outcomes of the practicum activities, facilitating a more comprehensive understanding of the concepts related to water and air pollution (Wahyuni et al., 2018; Yuliyanti et al., 2019; Larasati et al., 2021; Melisa, 2021).

There are several research related to perception. First is one research of student's perception towards online learning. This research concludes that students perceive that face-to-face learning is preferable than online learning, of which is mainly influenced by support and facilities that they have access to during the pandemic (Estigarribia et al., 2022; Kaya & Akdinez, 2004). There is one other research of which implement environment power monitoring and its impact towards student's STEM perception (Mang et al., 2023. Keznek et

al., 2004). This research finds that by implementing said method, student gain better understanding of STEM knowledge, perceive science as more exciting, and increase student's aspirations towards STEM-related professions (Mang et al., 2023; Keznek et al., 2004). Finally, many research discussing the use of SSIs on the topic of climate change concluded that in the topic of science-biology content (Afriani, 2018; Amah et al., 2023; El Takach & Al Tobi, 2021), socio-critical (Saija et al., 2022), problem-oriented approach (Sari & Wiyarsi, 2020), to teaching allows for innovation in science classrooms and leads to higher levels of motivation (Schyns, 2010; Knezek et al., 2013), and a greater perception of the relevance of science for everyday life (Feierabend & Eilks, 2010). However, the research on students' perceptions in science learning at the senior high school level especially in biology has not been conducted directly and has not yet focused on students' perceptions of a particular subject.

Therefore, there is a need for us to better understand how student's perceive SSIs related to the environment (Wahyuni et al., 2018; Yuliyanti et al., 2019; Taber et al., 2021; Larasati et al., 2021; Melisa, 2021; Forgione et al., 2023). By doing so, we can better devise a strategy to help student gain better perception towards SSIs of environment. Of course, ideally this research should be conducted on students with a focus in biology education. The research questions proposed in this study are:

1. How are the students' perception towards socio-scientific issues in biology learning among senior high school students?
2. How are the students' perception towards socio-scientific issues in biology learning based on class grade?
3. How are the students' perception towards socio-scientific issues in biology learning based on genders?
4. How is the correlation between students' motivation and self-regulation in science learning among junior high school students?

METHOD

Research Design

The research approach employed in this study involves case study with cross-grade survey model utilizing the one-single survey (Kazdin, 2011, Cresswell, 2014; Çalik et al., 2015; Er-Nas & Çalik, 2018). The descriptive quantitative statistical analysis method was employed to profile student's perception on socio-scientific issues in biology learning (Cresswell, 2014). This methodology was chosen due to the inherent requirement for comparison between two distinct of grade classes, and genders. Figure 1. Shows research design flowchart.

Based on Figure 1, which is the deciding Stage, we start by brainstorming the students' perceptions towards socio-scientific issues (SSI) in biology education. This process involves gathering initial thoughts and ideas from students regarding various socio-scientific issues they encounter or find relevant. After understanding their perspectives, we move on to deciding on a specific project that the students will undertake, ensuring it aligns with their interests and educational objectives. Concurrently, we conduct a comprehensive literature review to understand existing research and theories related to students' perceptions of SSI in biology education . This step helps to ground our project in established academic work and identify gaps that our research might fill. Following the literature review, we sketch the initial research project, outlining its objectives, methodology, and expected outcomes. The final part of this stage involves designing a detailed questionnaire aimed at gauging students' perceptions towards SSI in biology education, ensuring it is thorough and capable of capturing nuanced responses.

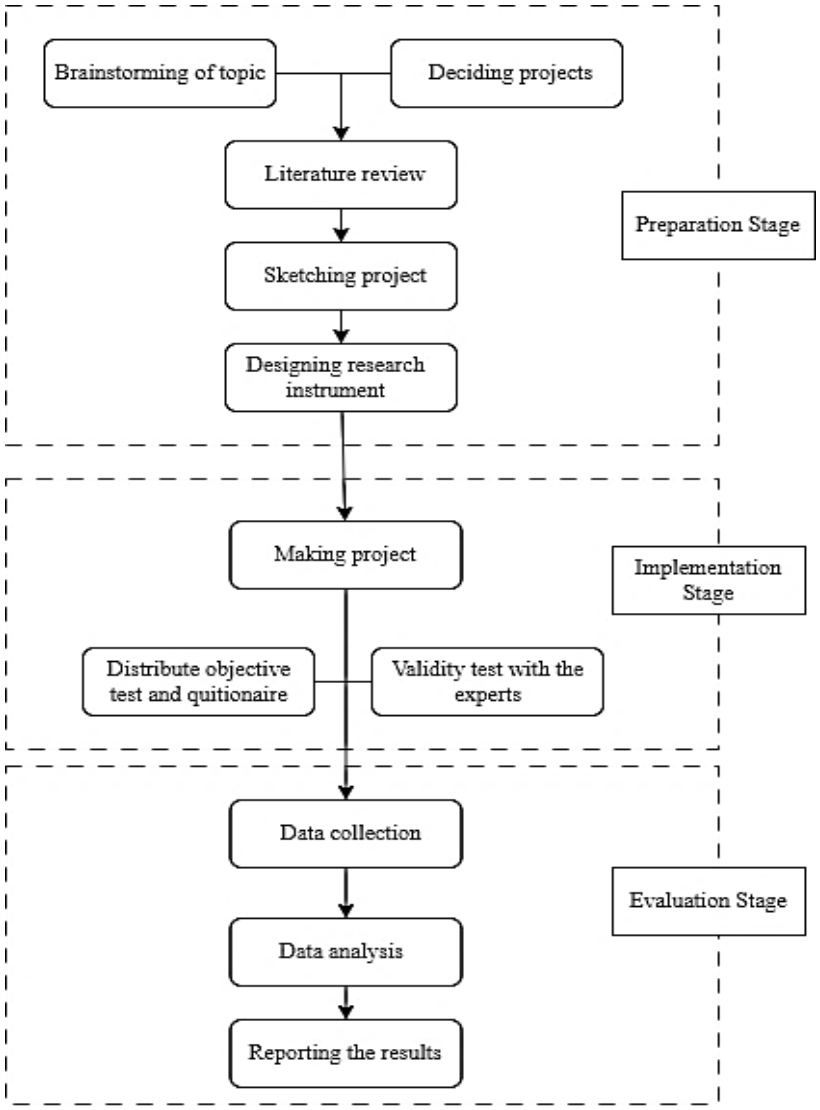

Figure 1. Research Design Flowchart.

During the implementation stage, our primary focus is on developing reliable and valid instruments to assess students' perceptions of SSIs in biology education. This process involves designing, refining, and finalizing the questionnaire and any additional tools required for data collection. Once the instruments are prepared, they are distributed to the target student group, accompanied by clear instructions to ensure accessibility and ease of use. To enhance the accuracy and relevance of the instruments, we engage subject matter experts to review and validate the questionnaire. This validation process includes evaluating the clarity, relevance, and comprehensiveness of the items, followed by refining the instruments based on expert feedback to ensure they meet the highest standards of quality and rigor.

Finally, in the Evaluation Stage, we systematically collect the completed questionnaires and other data from both the students and the experts who reviewed our instruments. We then proceed with a detailed data analysis, utilizing appropriate statistical methods to interpret the results. This analysis helps us understand the students' perceptions in depth and draw meaningful conclusions. The final step of this stage is reporting the findings in a structured format, which

may include written reports, presentations, or publications, ensuring that the results are communicated effectively to all stakeholders, including students, educators, and researchers.

Participant

The participants in this research were senior high school students who had previously studied environmental pollution. The study was conducted in public senior high schools in Majalengka, West Java, Indonesia, involving a total of 360 participants aged 16–19 years (130 males and 230 females). Of these, 180 students were from the 10th grade, and 180 were from the 11th grade. Participants were selected using purposive sampling, a technique based on specific criteria. Purposive sampling involves selecting participants based on informed judgment, allowing researchers to choose individuals who are most appropriate for the study based on prior knowledge and specific considerations (Fraenkel et al., 2011). Considerations guiding participant selection included budget, resources, and time. The participant distribution can be seen on Table 1.

Table 1. Participant Distribution.

		f	%
Gender	Male	130	36.11 %
	Female	230	63.89 %
Total		360	100 %
Class	10^{th} Grade	180	50 %
	11^{th} Grade	180	50 %
Total		360	100 %

Research Instruments

The purpose of the 5-point Likert scale questionnaire survey is to investigate and profile students' perceptions of socio-scientific issues (SSI), with a specific focus on biology learning in this research. The 5-point Likert scale questionnaire was employed as a key instrument for data collection. The survey items were designed based on a valid rubric adapted from the research by Subiantoro and Treagust, which explored socio-scientific issues in biology education at the university level (Subiantoro & Treagust, 2021). The investigation of students' perception towards socio-scientific issues in biology learning, as envisioned in this research, employs student's perception rubric encompassing four key indicators: Contextualization of SSI, Student Involvement, attitude towards SSI-Learning, and SSI-learning objective yet beneficial for formulating actionable steps. The initial blueprint of the survey items, prior to undergoing analysis, is presented in Table 2.

Table 2. The 5-likert Questionnaire survey of Students' Perception.

Indicator of Student's Perception towards SSI	Question Number	Total	Percentage
Contextual of SSI	1,2,3,4,5,6	6	25%
Student Involvement	7,8,9,10,11,12,13	7	29%
Attitude towards SSI-Learning	14,15,16,17,18	5	20%
SSI-Learning Objectives	19,20,21,22,23,24	6	25%
Total	**24**		**100%**

Data Analysis

The survey score was derived from the data collected using 24 items in a 5-point Likert scale questionnaire. Each accurate response to a question was assigned a score of 5, while an erroneous response received a score of 0. The assessment scores reflect students'

perceptions of SSI, as conceptualized by Subiantoro and Treagust (2021). The data were analyzed by calculating the mean and standard deviation of the scores obtained. The interpretation of the data is presented in Table 3.

Table 3. Data Interpretation of Survey Result of Students Perception towards Socio-Scientific Issues in Biology Learning.

Mean Scores	Level of Interpretation
4.01 – 5.00	Very Agree
3.01 – 4.00	Agree
2.01 – 3.00	Neutral
1.01 – 2.00	Disagree
0.00 - 1.00	Very Disagree

Source: (Subiantoro & Treagust, 2021).

To examine the correlation between students' perceptions and socio-scientific issues (SSI) among senior high school students, Spearman's rho analysis was employed, as the data did not meet the assumption of normality. Additional descriptive statistics, including means and standard deviations, were also analyzed to provide a comprehensive overview of the data. All analyses were conducted using IBM SPSS Statistics (Version 23). The detailed interpretation of the results is presented in Table 4.

Table 4. The category of Spearman's Rho Correlation about Students' Perception towards Socio-Scientific Issues.

Grading Standards	Correlation Degree
$\rho = 0$	No correlation
$0 < \|\rho\| \leq 0.19$	Very week
$0.20 \leq \|\rho\| \leq 0.39$	Weak
$0.40 \leq \|\rho\| \leq 0.59$	Moderate
$0.60 \leq \|\rho\| \leq 0.79$	Strong
$0.80 \leq \|\rho\| \leq 1.00$	Very strong
1.00	Monotonic correlation

RESULT AND DISCUSSION

Student's Perception towards Socio-Scientific Issue in Biology Learning

Students' perceptions of SSI in biology learning were assessed by administering a 5-point Likert scale questionnaire to all participants in the 10th and 11th grades. The survey was conducted once, immediately after the students completed their biology learning sessions. This research was carried out in public senior high schools in Majalengka, Indonesia, involving students from both grade levels.

The indicators of students' perception used in this research were adopted from Subiantoro and Treagust (2021), who developed a survey to assess students' perceptions of socio-scientific issues (SSI). The survey consisted of 25 items structured as a 5-point Likert scale questionnaire, covering five key aspects of students' perception indicators: Contextualization of SSI (C-SSI), Student Involvement (SI), Attitude towards SSI Learning (A-SSIL), SSI Learning Objectives (SSI-LO), and related skills. The questionnaire underwent rigorous validation processes, including tests for validity, normality, and reliability. Additionally, the instrument was evaluated by three subject-matter experts, ensuring it met the criteria for a valid and reliable measure of students' perceptions of SSI in biology learning. A summary of the total scores from the students' perception survey regarding SSI in biology learning is presented in Table 5.

Table 5. Summary of Total Average of Student's Perception towards SSI in Biology Learning.

Component	C-SSI	SSI-LO	SSI-LO	A-SSIL	Total Participants	Total Average of Students' Perception towards SSI
$\bar{x}$	3.28	3.33	3.29	3.32		3.31
(Interpretation)	Neutral	Neutral	Neutral	Neutral	360 Senior	Neutral
SD	1.20	1.29	1.19	1.18	high school	1,21
Highest score	1	1	1	1	students	1
Lowest score	5	5	5	5		5

Based on Table 5 the total average score about students' perception towards socio-scientific issues in biology learning is 3.31 (SD 1.21) interpreted as neutral perception. Furthermore, the total average for C-SSI is 3.28 (SD 1.20) interpreted as neutral, for SSI-LO is 3.33 (SD 1.29) interpreted as neutral, for A-SSIL is 3.29 (SD 1.19) and for A-SSIL is 3.35 (SD 1.18) interpreted as a neutral. This finding is further explained by other results of the lowest and highest scores in total participants which show the similar results trend. Figure 2 shows the total average score of student's perception towards SSI in biology learning.

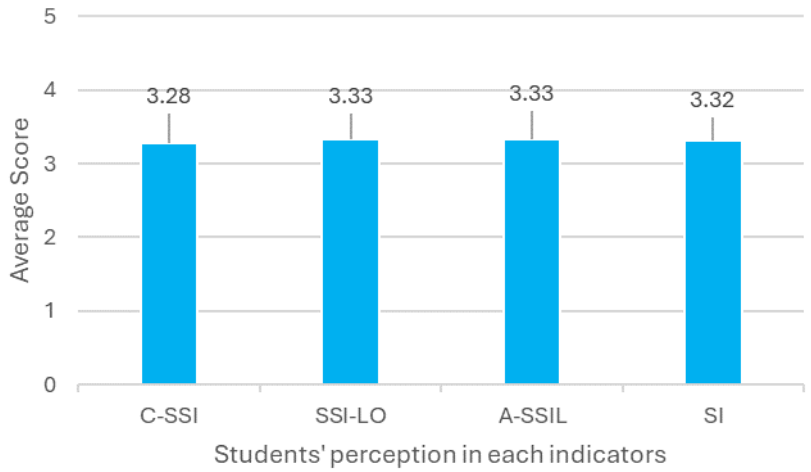

Figure 2. Total Average Score of Student's Perception towards SSI in Biology Environmental Pollution Topic.

Figure 2 confirms the finding in Table 5, which shows the increasing trend in the total average score of students' Perception that students achieved after participating in the learning biology. The result of students 'perception towards SSI indicators, C-SSI, SSI-LO, A-SSIL, and SI have average score 3.28 – 3.33. If the total average score of each indicator is immerge, the total average of students' perception towards SSI in Biology learning is 3.31 that interpreted as neutral perception.

The average score analysis was conducted to evaluate students' perceptions of Socio-Scientific Issues (SSI) in the treated classes, focusing on differences between the outcomes of 10th-grade and 11th-grade students. The total average score in the 10th-grade class was 3.30 (SD = 1.24), categorized as neutral, with a score distribution of 3.28 for male students and 3.33 for female students. Similarly, the total average score in the 11th-grade class was 3.32 (SD = 1.18), also interpreted as neutral, with male students scoring 3.29 and female students scoring 3.35.

The results indicate an increasing trend in the total average scores before and after the implementation of treatment in both classes. This suggests that students are beginning to connect their learning with the context of SSI, demonstrating a positive shift in their perceptions. Additional analysis of the lowest and highest scores in both classes also revealed a similar increasing trend, supporting the overall findings. Figure 3 illustrates the average scores of students' perceptions towards SSI in biology learning across both grade levels, providing a visual representation of these trends.

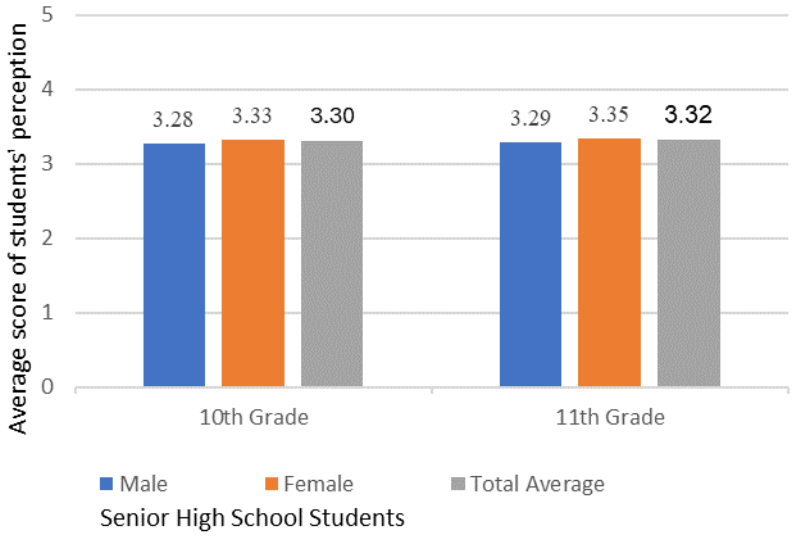

Figure 3. The Average Score of Student's Perception towards SSI In Biology Learning Based on Grade Level.

Figure 3 confirms the findings, illustrating the increasing trend in the total average score of students' perceptions after participating in biology learning. This indicates a positive shift in students' perceptions toward Socio-Scientific Issues (SSI) during the learning process. However, the results suggest that, overall, students' perceptions remain in the neutral category when analyzed based on grade level. This interpretation highlights the need for further exploration of teaching strategies to strengthen students' connections with SSI in biology learning.

Table 6. Summary of Total Average of Student's Perception towards SSI in Biology Learning.

Component	Male		Total Average in male students	female		Total Average in female students
	10th grade	11th grade		10th grade	11th grade	
Participants	63	67		127	113	
$\bar{x}$	3.28	3.29	3.28	3.33	3.35	3.34
(Interpretation)	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral
SD	1.20	1.19	1.19	1.29	1.18	1.23
Highest score	1	1	1	1	1	1
Lowest score	5	5	5	5	5	5

A statistical survey was conducted to evaluate students' perceptions of Socio-Scientific Issues (SSI) in biology learning based on gender differences (male and female students). The summary of students' total perception scores is presented in Table 6. According to the data, the total average score for male students was 3.28 (SD = 1.19), while the average score for female

students was slightly higher at 3.34 (SD = 1.23), with both categories interpreted as neutral.

The results demonstrate a consistent trend of increasing average scores for both genders following the implementation of biology learning. This suggests that both male and female students are progressively connecting their learning with the context of SSI. Additional analysis of the lowest and highest scores for each gender also revealed a similar upward trend. Figure 4 provides a visual representation of the average perception scores toward SSI in biology learning, comparing male and female students.

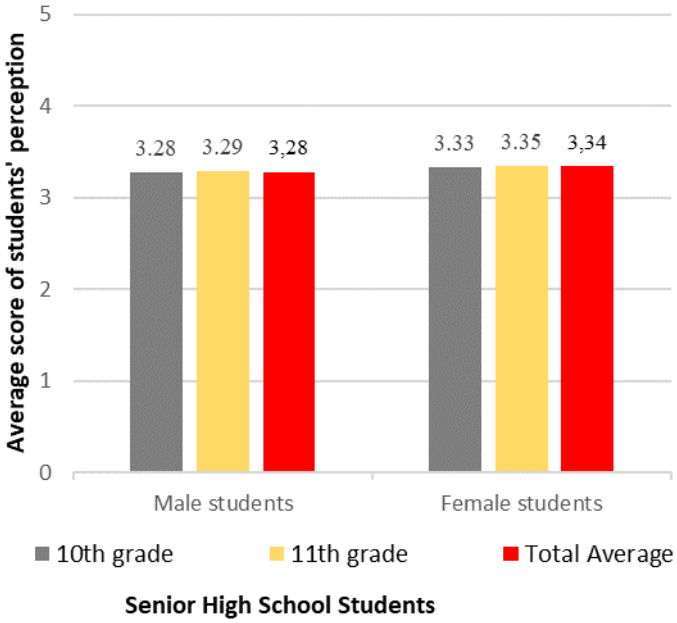

Figure 4. The Average Score of Student's Perception towards SSI in Biology Learning Based on Gender.

Figure 4 confirms the finding in Table 6, which shows the increasing trend in the total average score of students' Perception that students achieved after participating in the learning biology. Then, it can be interpreted that the implementation, student's perception towards SSI in biology learning are neutral based on gender.

Students' Perception about Socio-Scientific Issues (SSI) in Each Indicator

Using the same procedure employed to examine students' overall perceptions of socio-scientific issues (SSI) in biology education, individual indicators of perception toward SSI were also analyzed. The indicators assessed in this research include Contextualization of SSI (C-SSI), Student Involvement (SI), Attitudes Toward SSI-Learning (A-SSIL), and SSI-Learning Objectives (SSI-LO). Table 8 provides a summary of the descriptive statistics profiling students' perceptions of SSI in biology learning.

Based on Table 7, the perception of students towards SSI in biology education about environmental pollution, both in terms of gender and grade level, towards SSI (Science, Society, and Environment) in the field of Biology. The observation indicates that the perception of students across all categories regarding SSI in Biology is generally above 3 but below 3.5. This suggests that students' perceptions of SSI in the subject of Biology tend to be neutral Fuentes & Entezari, 2020; Owens et al., 2021).

Table 7. Descriptive Statistics of the Profile of Students' Perception towards SSI in Biology Learning.

		Sample (n)		C-SSI	SSI-LO	A-SSIL	SI
Gender	**Male**	130	Average	3.28	3.33	3.33	3.32
	Female	230	Average	3.30	3.33	3.33	3.33
Total				**360 students**			
Class	**10th Grade**	180	Average	3.30	3.33	3.33	3.33
	11th Grade	180	Average	3.28	3.33	3.33	3.32
Total				**360 students**			

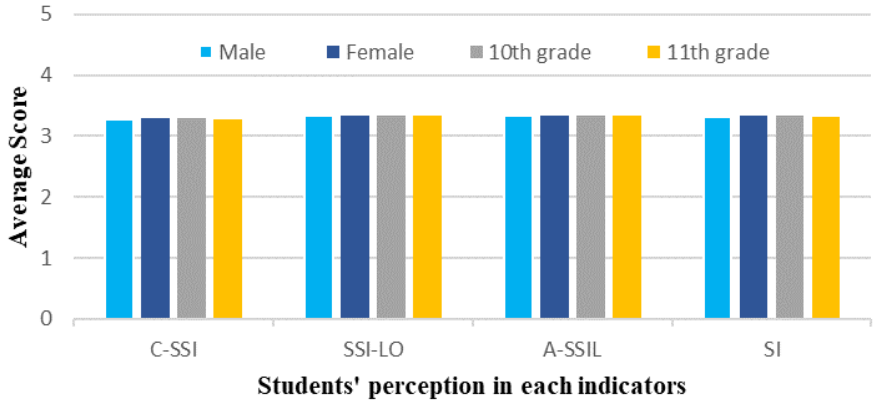

Figure 5. Average Score in Students' Perception towards SS Indicators.

Based on Table 7 and Figure 5, students' perceptions across all categories regarding Socio-Scientific Issues (SSI) in biology fall within the range of 3 to 3.5, indicating a generally neutral perception. This suggests that while students recognize the relevance of SSI in biology learning, their attitudes are not strongly positive. The contextualization of Socio-Scientific Issues (C-SSI) involves integrating scientific topics that require students to engage in dialogue, discussion, and debate. These topics typically involve controversial and open-ended problems with multiple solutions, encouraging critical thinking and collaborative problem-solving (Wahyuni et al., 2018; Yuliyanti et al., 2019; Taber et al., 2021; Larasati et al., 2021; Melisa, 2021; Forgione et al., 2023). The primary goal of this approach is to promote scientific literacy, intellectual growth, moral development, and active community engagement in local, social, and global contexts.

The findings align with previous research suggesting that students generally hold positive but moderate attitudes toward SSI-based learning experiences, finding them relevant but not strongly impactful (Barry et al., 2023; Kaya & Akdinez, 2004; Subiantoro, 2021). Figure 5 illustrates students' active engagement during biology learning activities, highlighting their interaction and participation in SSI-based discussions. This suggests potential for further development in teaching strategies to strengthen students' positive perceptions and deepen their engagement with SSI in biology education.

Figure 6. The Activity of Student's Activity in Biology Learning.

Figure 6 illustrates that student involvement (SI) in SSI-based learning is essential, as it encourages students to present informed opinions grounded in appropriate conceptualizations of science, fostering enhanced scientific literacy and informed citizenship. Research on student involvement indicates that biology students generally believe SSI should be included in their curriculum; however, their attitudes remain moderately positive (Barry et al., 2023; Kaya & Akdinez, 2004; Subiantoro, 2021). Attitude towards Socio-Scientific Issues Learning (A-SSIL), another key indicator, reflects students' disposition toward SSI-based instruction. This is significant in democratic societies, where socio-scientific issues often spark public debates, and participation in such discussions mirrors individuals' attitudes toward these issues as enduring evaluative judgments (Türk & Çam, 2024; Mejía-Cáceres et al., 2023; Sanchez et al., 2024; Ke et al., 2021; Bromme & Goldman, 2014; Sinatra et al., 2014). However, the phenomenon of myside bias implies that individuals' prior attitudes influence their evaluation of evidence and hypotheses, particularly in controversial contexts (Stanovich et al., 2013). The neutral attitudes towards SSI-based learning observed in this study may stem from the complexity and contentious nature of SSI topics (Mejía-Cáceres et al., 2023; Sanchez et al., 2024; Ke et al., 2021), which demand shifts in students' perceptions of science education (Türk & Çam, 2024).

The Socio-Scientific Issues Learning Objective (SSI-LO) encompasses outcomes such as decision-making skills, scientific literacy, intellectual growth, moral development, and community engagement across various contexts (Wahyuni et al., 2018; Yuliyanti et al., 2019; Taber et al., 2021; Larasati et al., 2021; Melisa, 2021; Forgione et al., 2023). However, the lack of guidance for teachers in selecting focal issues for SSI-based learning may contribute to students' neutral attitudes (Türk & Çam, 2024).

The neutral perceptions in categories such as contextualization of SSI (C-SSI), SI, A-SSIL, and SSI-LO may arise from several factors. First, socio-scientific issues often present multifaceted problems without definitive solutions, challenging students to form strong attitudes (Fuentes & Entezari, 2020; Owens et al., 2021). Second, biology as a discipline closely relates to many SSI topics, such as pollution and health, but the diversity of perspectives on these issues may contribute to overall neutral perceptions (Barry et al., 2023; Kaya & Akdinez, 2004; Subiantoro, 2021). Third, limited exposure to SSI topics or inadequate engagement in related activities might result in weaker opinions (Fuentes & Entezari, 2020; Owens et al., 2021). Fourth, traditional teaching approaches may fail to integrate SSI effectively, reducing students' involvement and engagement (Türk & Çam, 2024). Fifth, the tools used to measure perceptions may inadequately capture the nuances of students' experiences, contributing to neutral responses. Sixth, teachers play a critical role in shaping perceptions; if they do not highlight the relevance of SSI in biology, students may not form strong opinions (Mang et al., 2023; Keznek et al., 2004; Wahyuni et al., 2018; Yuliyanti et al., 2019; Taber et al., 2021; Larasati et al., 2021; Melisa, 2021; Forgione et al., 2023).

To foster positive attitudes towards SSI-based learning, several strategies can be implemented. First, preservice and in-service teacher training on SSI can improve teachers' competence and influence students' attitudes positively (Wahyuni et al., 2018; Yuliyanti et al., 2019). Second, integrating SSI into biology instruction allows students to explore scientific content in a contextualized manner, promoting engagement and positive

attitudes. Third, teachers should develop their expertise in SSI by collaborating with local communities and experts on relevant social issues, such as environmental pollution (Owens et al., 2021). Fourth, carefully selecting focal SSI topics can enhance students' engagement and interest in these issues (Türk & Çam, 2024). Fifth, combining SSI-based instruction with assessments provides students with opportunities to reason and reflect on their learning, helping teachers address gaps in their understanding. By adopting these strategies, teachers can enhance students' scientific literacy, critical thinking, and decision-making skills, fostering more positive attitudes towards SSI-based learning (Taber et al., 2021; Larasati et al., 2021; Melisa, 2021; Forgione et al., 2023).

The Correlation Between Students' Perception and Socio-Scientific Issues

The data analysis confirmed that the distribution was normally distributed, and the Spearman's Rho method was employed to test the correlation between variables. The results, as shown in Table 8, indicate that students' perceptions have a weak correlation with socio-scientific issues (SSI) in biology learning, with a correlation coefficient of $r = 0.08$ and a significance level of $p = 0.002$ ($p < 0.05$). While the correlation is statistically significant, the weak coefficient suggests a minimal relationship between the variables. This weak correlation implies that as students' perceptions of SSI increase, there is only a slight corresponding change in their engagement with SSI, and vice versa. In practical terms, this may indicate that more motivated students tend to exhibit slightly higher self-regulation in their learning activities.

Further analysis of specific indicators, including Contextualization of SSI (C-SSI), Attitude towards SSI Learning (A-SSIL), Student Involvement (SI), and SSI Learning Objectives (SSI-LO), also revealed weak correlations with socio-scientific issues in biology learning. The weak correlations may be influenced by various factors, including the complexity and controversial nature of socio-scientific issues, teaching methods, and individual differences among students.

Table 8. Result of Spearman's Correlation between Motivation and Self-Regulation.

	Variables	Correlation (r)	Sig. (p)	Explanation
Spearman's Rho Correlation	Correlation between students' perception and socio-scientific issues in Biology learning	0.08	0.002	Weak correlation

Research highlights that students' perceptions of the relevance of science teaching and their capacity to engage with authentic, controversial socio-scientific issues significantly impact their understanding and decision-making abilities (Archila et al., 2023; Marandino et al., 2023; Richardson & Lacroix, 2021; Subiantoro & Treagust, 2021). Additionally, the impact of student-curated exhibitions about SSI varies, with limited influence observed in countries where such activities are not novel. Studies also emphasize the role of personal beliefs and values in shaping students' perceptions of science and science-related careers, further underscoring the multifaceted nature of these perceptions (Barry et al., 2023; Kaya & Akdinez, 2004; Subiantoro, 2021).

SSI-based instruction has been shown to enhance students' interest and motivation, improve their understanding of the nature of science, and develop higher-order thinking skills. Teaching science within the context of SSI helps students connect scientific knowledge

with societal dimensions, enabling them to make informed decisions (Richardson & Lacroix, 2021; Subiantoro & Treagust, 2021). Engaging students in exploration and interactive activities also fosters greater interest and motivation in learning about SSI (Zidny & Eilks, 2020; Zowada et al., 2018). Furthermore, student-curated exhibitions and real-world problem-solving activities positively impact students' perceptions and competencies regarding SSI.

To strengthen students' engagement with SSI, educators should incorporate real-world issues, hands-on activities, and student-centered approaches into their teaching strategies (Mang et al., 2023). Encouraging students to participate in community projects, volunteer activities, or observe societal and environmental impacts in their surroundings can deepen their understanding of SSI and enhance their motivation to learn. Such strategies can help bridge the gap between students' perceptions and active engagement with socio-scientific issues, fostering scientific literacy and critical thinking skills essential for navigating complex real-world challenges.

CONCLUSION

The findings reveal that students generally hold a neutral perception of socio-scientific issues (SSI) related to environmental pollution, with no significant differences observed across gender or grade levels. Similarly, students' perception of biology learning is neutral, with some uncertainty regarding the relevance of biology concepts to their daily lives, indicating a consistent but limited engagement with SSI. These results suggest a need for further exploration to enhance students' understanding and involvement in SSI-based learning. Future research should investigate additional factors, such as cultural, social, and pedagogical influences, that may shape students' perceptions of SSI. Moreover, experimenting with alternative learning models could provide valuable insights into improving students' engagement with SSI in biology lessons. However, the findings of this study are limited to three regions in Majalengka, West Java, Indonesia, which constrains their generalizability. Expanding the geographical scope in future studies is recommended to obtain more comprehensive and representative data.

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