



Development of a socio-scientific issues-based electronic module on ecosystem material to enhance students' reflective thinking and scientific argumentation skills

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Abstract. This study aims to determine the feasibility, practicality, and effectiveness of an electronic module based on Socio-Scientific Issues (SSI) on ecosystem material to improve students' reflective thinking and scientific argumentation skills. The study used the Research and Development method with the ADDIE model, which includes the stages of analysis, design, development, implementation, and evaluation. The product developed is an electronic module based on SSI. The feasibility of the module was assessed through validation by material and media experts, while practicality was assessed by teachers and students using questionnaires and interviews. Data on reflective thinking and scientific argumentation skills were obtained through pretests and posttests. Data analysis of feasibility and practicality was carried out descriptively using Likert and Guttman scales. Reflective thinking skills were analyzed using the Mann-Whitney U test, while scientific argumentation was analyzed using the Wilcoxon test and Toulmin argumentation patterns. The results showed that the module met the criteria for being highly feasible and practical for use in learning. The test results showed a sig value of 0.439 for the control class, while 0.002 for the experimental class. Based on these results, the developed module is effective in improving students' reflective thinking and argumentation skills. The use of the module also improved students' reflective thinking and scientific argumentation skills, although the N-gain score in the experimental class was still in the lower category compared to the control class. The results of this research can be used by teachers as an alternative teaching material in the classroom.

Keywords: *Ecosystem, Electronic module, Reflective thinking, Scientific argumentation, Socio-scientific issues*

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INTRODUCTION

In the Independent Curriculum, scientific argumentation skills are a crucial competency. Through scientific argumentation, students learn to express opinions based on valid data and evidence, conduct analysis and evaluation, and express ideas logically (Muhidin, 2024). However, field conditions indicate that students' scientific argumentation skills remain low due to limited practical experience and less interactive learning (Amiruddin et al., 2025; Novianti et al., 2022; Hardini & Alberida, 2022). This low ability in scientific argumentation is evident in the results of the 2022 Program for International Student Assessment (PISA), in which Indonesia achieved an average science score of 383 and ranked 66th among 80 participating countries (OECD, 2022). Tama et al. (2019) stated that Indonesia's low PISA achievement in science is related to students' weak science process skills, including scientific communication skills. Therefore, improving students' communication skills requires familiarization and training in scientific argumentation. Furthermore, learning that lacks interaction and practical activities leads students to focus more on memorizing material without developing comprehensive scientific argumentation skills (Siregar & Pakpahan, 2020).

In addition to scientific argumentation, the Independent Curriculum also requires students to master reflective thinking skills. Peraturan Menteri Pendidikan Dasar dan Menengah Republik Indonesia Nomor 13 Tahun 2025 emphasizes the need for a conducive learning environment and a meaningful learning process to enable students to develop 21st-

century competencies, including reflective, critical, and creative thinking. This regulation emphasizes deep learning grounded in the principles of conscious, meaningful, and enjoyable learning and forms a holistic student profile encompassing faith, citizenship, literacy, and higher-order thinking skills, including scientific argumentation and reflective thinking (Paidit et al., 2026). This underscores the importance of learning models that encourage active, reflective, and critical thinking at all levels of education.

One strategy is to integrate science-based social issues through the Socio-Scientific Issues (SSI) model. The SSI model encourages students to analyze problems from multiple perspectives, develop evidence-based arguments, and reflect on social and ethical implications (Ismawati, 2019; Sari et al., 2021; Hancock et al., 2019; Dewi et al., 2023). Active student involvement through discussion, debate, and data collection makes the resulting solutions contextual and relevant to real-world problems, while also fostering reflective thinking and scientific argumentation skills. In the process, the teacher serves as a facilitator, guiding the discussion among students.

To hone students' reflective thinking and scientific argumentation skills, teachers can implement various innovations, such as the development of teaching materials. One recommended innovation is the creation of electronic modules (Dwi et al., 2024). This electronic module is a learning medium containing text and images. It offers advantages such as portability, ease of distribution, durability, and accessibility to various user groups (Nasution, 2024). Electronic modules serve as a tool in the learning process, containing systematically and engagingly designed teaching materials to support students in achieving the expected competencies (Atiqoh & Suhandoyo, 2022).

Ecosystems is a biological subject that can be contextualized through problems encountered in everyday life. This material can be linked to various relevant socio-scientific issues, thus offering potential for use in learning to train students' reflective thinking and scientific argumentation skills. Ecosystems play a central role in enhancing students' reflective thinking and awareness of increasingly complex environmental issues, such as habitat destruction and biodiversity decline. This material contains concepts highly relevant to everyday life, as well as social and ecological issues that require an in-depth understanding and responsible responses from the younger generation to support environmental sustainability (Miterianifa & Mawarni, 2024). From an educational perspective, ecosystem material has great potential to be used as a medium to develop reflective thinking skills and scientific argumentation because issues related to ecosystems are often multidimensional and controversial, thus requiring students to be able to analyze, evaluate scientific information, and build arguments based on data and consider social and ethical aspects in their resolution (Miterianifa & Mawarni, 2024). Given the above background, it is important to develop an electronic module to improve students' reflective thinking skills and scientific argumentation. This research is expected to serve as an alternative teaching material for teachers in schools.

METHOD

This study employed the Research and Development (R&D) approach using the ADDIE model, including Analyze, Design, Development, Implementation, and Evaluation (Branch, 2009). The product trial design used was a non-equivalent control group design. The product was assessed by lecturers who were material experts, lecturers who were media experts, biology teachers, and students. Data collection techniques and instruments used in this study were interviews, questionnaires, and pretest-posttest questions. Data analysis techniques included assessments of product feasibility, practicality, and effectiveness. The feasibility analysis by the material validator was conducted using a questionnaire based on the Guttman scale with two response options, "yes" and "no," as presented in Table 1.

Table 1. Guttman scale criteria

Score	Description
1	Yes
0	No

The feasibility and practicality analysis was conducted by calculating the average score for each questionnaire aspect. The score for each aspect was obtained by converting qualitative answers into quantitative ones using a Likert scale with the following provisions (Suryani, 2015).

$$\text{Value of each aspect} = \frac{\text{Average score}}{\text{Maximum score}} \times 100$$

In addition, the score for each aspect of the feasibility of the concept truth aspect by the material validator is expressed as a percentage using the following formula (Suryani, 2015).

$$P = \frac{\sum x}{\sum xi} \times 100\%$$

Description:

P : percentage score

$\sum$: total score obtained

$\sum xi$: maximum score

The feasibility and practicality validation percentages are categorized according to the criteria in Table 2.

Table 2. Criteria for the feasibility and practicality of the electronic module

Category	Value
Very suitable	81 – 100
Suitable	61 – 80
Moderate	41 – 60
Unsuitable	21 – 40
Very unsuitable	≤ 20

Observations of learning implementation were analyzed using a Guttman scale-based observation sheet, with the percentage of implementation calculated as follows.

$$p_{\text{implementation}} = \frac{\sum \text{Measured indicator}}{\sum \text{Total indicator}} \times 100\%$$

The effectiveness of the Socio-Scientific Issues-based electronic module on students' reflective thinking and scientific argumentation skills was assessed using pretest and posttest questions administered to students in the control and experimental classes. The improvement in each of these two skills was analyzed using the gain normalization technique, as follows (Meltzer, 2002).

$$N - \text{gain} = \frac{S_{\text{post}} - S_{\text{pre}}}{S_{\text{maks}} - S_{\text{pre}}}$$

The analysis results are then determined using the following gain-normalization criteria (Table 3).

Analysis of learning implementation is carried out by calculating the results of the learning implementation observation sheet using the following formula.

$$\text{Implementation} = \frac{\sum \text{Measured syntax}}{\text{Total sintaks}} \times 100\%$$

Table 3. Criteria for normality values of gain

No	Classification	Value
1	High	$g > 0.70$
2	Medium	$0.30 < g \leq 0.70$
3	Low	$g \leq 0.30$

Then, the implementation percentage is categorized according to [Arikunto and Jabar \(2010\)](#), as shown in Table 4.

Table 4. Percentage category of learning implementation

Percentage of implementation	Criteria
$80\% < X \leq 100\%$	Very good
$65\% < X \leq 80\%$	Good
$55\% < X \leq 60\%$	Moderate
$40\% < X \leq 40\%$	Poor
$X \leq 40\%$	Very poor

RESULTS AND DISCUSSION

Results

The product of this research is an electronic module based on socio-scientific issues on ecosystems for 10th-grade high school students, designed to support the development of reflective thinking and scientific argumentation skills. The presentation of the research results is structured based on the ADDIE development stages.

Analysis Stage

The needs analysis aimed to identify gaps between current and desired conditions. Information was collected through interviews with biology teachers and questionnaires completed by 11th-grade students regarding the learning process, student characteristics, learning tools, media, and facilities used. The analysis revealed several important findings. Teachers rarely applied issues as a learning context. Furthermore, students agreed that learning would be more engaging when using electronic media, as they considered it more interactive. Students' scientific argumentation and reflective thinking skills were relatively low, as evidenced by arguments that did not meet scientific criteria. This situation was exacerbated by the limited learning media, which consisted of PowerPoint presentations and lectures, as well as limited learning resources. Students felt bored when learning was dominated by lectures, but enthusiastic when technology was used.

Design Stage

This stage involves developing learning products based on the previously conducted needs analysis. This stage ensures that the developed Socio-Scientific Issues-based electronic module aligns with student needs and learning objectives. The results of this stage include learning, product, and instrument designs. The electronic module is systematically structured, including the front cover, module identity, foreword, user manual, table of contents, list of tables, concept map, introduction, learning activities, assessments, glossary, bibliography, and information about the electronic module.

Development Stage

This stage involves an assessment of the electronic module by validation experts before it is implemented in the classroom to ensure that the learning tool meets the eligibility criteria.

After receiving assessments, suggestions, and comments from the validators, revisions are made to address deficiencies in the electronic module's development.

Material Expert Validation

The electronic module was validated by a material expert, a lecturer from the Biology Education Study Program at Yogyakarta State University. The material expert validated the material presented. The material expert assessed the conceptual validity of the 46 concepts outlined in the assessment instrument. The results of the assessment of the correctness of the material concept are presented in Table 5.

Table 5. Results of the assessment of conceptual truth aspects by experts		
Subject matter expert	Frequency of conceptual truth aspect criteria	
	Correct	Incorrect
Total score	45	1
Maximum score		46
Percentage	98%	2%

In addition to assessing conceptual accuracy, the material experts evaluated the modules on four aspects: content, evaluation, language, and presentation. The assessment questionnaire used by the material experts is included in the appendix. The results of the electronic module assessment by the material experts are presented in Table 6.

Table 6. Results of the electronic module assessment by material experts					
No	Assessment Aspects	Score	Max Score	Percentage	Criteria
1.	Material	23	24	95	Very Eligible
2.	Evaluation	18	20	90	Very Eligible
3.	Language	18	20	90	Very Eligible
4.	Presentation	15	16	94	Very Eligible
Total		74	80	92	Very Eligible

Media Expert Validation

The developed electronic module was validated by a media expert in the Biology Education Study Program at the Faculty of Mathematics and Natural Sciences, Yogyakarta State University. The media expert validated aspects of design/graphics, presentation, appearance and language, and usability. The results of the media expert's assessment are presented in Table 7.

Table 7. Assessment results from media experts					
No	Assessment Aspects	Score	Max Score	Percentage	Criteria
1.	Design/Graphics	20	20	100	Very Eligible
2.	Presentation	20	20	100	Very Eligible
3.	Appearance and Language	20	20	100	Very Eligible
4.	Usage	20	20	100	Very Eligible
Total		80	80	100	Very Eligible

Assessment by Biology Teacher (practitioner)

The practicality test was conducted by a biology teacher. The aspects assessed were material, evaluation, language, presentation, design/graphics, and usability. The results of the biology teacher's assessment are presented in Table 8.

Student Responses

Students provided responses to the module using a questionnaire. This assessment was conducted by reviewing aspects of the material, presentation, visuals and language, and independence. The results of student responses are shown in Table 9.

Table 8. Assessment results by biology teachers

No.	Aspects	Score	Max score	Percentage	Criteria
1.	Material	37	44	84	Very Eligible
2.	Evaluation	15	20	75	Very Eligible
3.	Language	20	20	100	Very Eligible
4.	Presentation	9	12	75	Very Eligible
5.	Design/Graphics	22	24	92	Very Eligible
6.	Use	14	16	87,5	Very Eligible
Total		117	136	86	Very Eligible

Table 9. Results of student responses

No.	Aspects	Score	Max Score	Percentage	Criteria
1.	Material	708	816	87	Very Eligible
2.	Presentation	473	544	87	Very Eligible
3.	Appearance and Language	923	1088	85	Very Eligible
4.	Independence	118	146	81	Very Eligible
Total		2.222	2.594	85	Very Eligible

Implementation stage

The effectiveness of SSI-based electronic modules on reflective thinking skills

Students' reflective thinking skills were measured before and after the implementation of the electronic module in learning using essay test questions. To determine whether both classes had similar initial abilities, a hypothesis test was conducted on the pretest data on reflective thinking skills. The results of the pretest data normality test are shown in Table 10.

Table 10. Pretest data normality test results

		Shapiro-Wilk		
	Class	Statistic	df	Sig.
Reflective Thinking	Control	.926	28	.050
	Experiment	.951	28	.210

Therefore, based on the Shapiro-Wilk normality test, the reflective thinking pretest data for the control and experimental classes are normally distributed. Next, a homogeneity test is conducted, as shown in Table 11.

Table 11. Results of the homogeneity test of reflective thinking pretest data

		Levene Statistic	df1	df2	Sig.
Reflective Thinking	Based on mean	.027	1	54	.871
	Based on Median	.124	1	54	.726
	Based on Median with adjusted df	.124	1	49.037	.726
	Based on trimmed mean	.016	1	54	.898

Based on the results of the normality and homogeneity tests above, the reflective thinking ability data were analyzed with parametric statistics, specifically the Independent Samples t-test. The results of the Independent Samples t-test are presented in Table 12.

Table 12. Results of the independent samples t-test for reflective thinking pretest data

		t	df	Sig. (2-tailed)
Reflective Thinking	Equal variances assumed	-.033	54	.974

Thus, it was concluded that there was no significant difference in the average pretest data between the control and experimental classes. This means that the initial reflective thinking skills of the control and experimental classes were the same. Furthermore, to test the effectiveness of the developed electronic module, a hypothesis test was conducted on the posttest data on students' reflective thinking skills. A description of the reflective thinking skills data is presented in Table 13.

Table 13. Descriptive Results of Reflective Thinking Ability Data

No	Description	Reflective Thinking			
		Control Class		Experimental Class	
		Pretest	Posttest	Pretest	Posttest
1	Minimum	17	22	28	39
2	Maximum	72	55	72	83
3	Mean	46.07	40.93	46.18	57.43
4	Std Deviation	12.570	8.777	11.457	12.357

The next test was used to determine the posttest scores for each class, which were then tested for normality and homogeneity. The following are the results of the normality test for the reflective thinking ability posttest data (Table 14).

Table 14. Results of the normality test for *posttest data* on reflective thinking ability

		Shapiro-Wilk	df	Sig.
Class		Statistics		
Reflective Thinking	Control	.931	28	.066
	Experiment	.933	28	.075

The significance value for both classes is greater than 0.05, indicating that the *posttest data* for reflective thinking ability are normally distributed. Next, a homogeneity test is performed, as shown in Table 15.

Table 15. The *posttest data* homogeneity test for reflective thinking ability

		Levene Statistics	df1	df2	Sig.
Reflective Thinking	Based on mean	6,848	1	54	.011
	Based on Median	4,914	1	54	.031
	Based on Median with adjusted df	4,914	1	52.556	.031
	Based on trimmed mean	6,851	1	54	.011

These results indicate that the data variance between the control and experimental classes is not homogeneous. Therefore, the *posttest data* on reflective thinking ability does not meet the assumption of homogeneity of variance. Furthermore, a nonparametric Mann-Whitney test was performed. The results of the Mann-Whitney test on reflective thinking ability data are presented in Table 16.

Table 16. Mann-Whitney test results for *posttest data* on reflective thinking ability

Reflective Thinking	
Mann-Whitney University	116,500
Wilcoxon W	522,500
Z	-4,566
Asymp. Sig. (2-tailed)	<0.001

It can be concluded that there is a significant difference between the *posttest scores* of the control class and the experimental class. The difference in reflective thinking skills between students in the control and experimental classes after using the SSI-based electronic module is shown in the following figure (Figure 1).

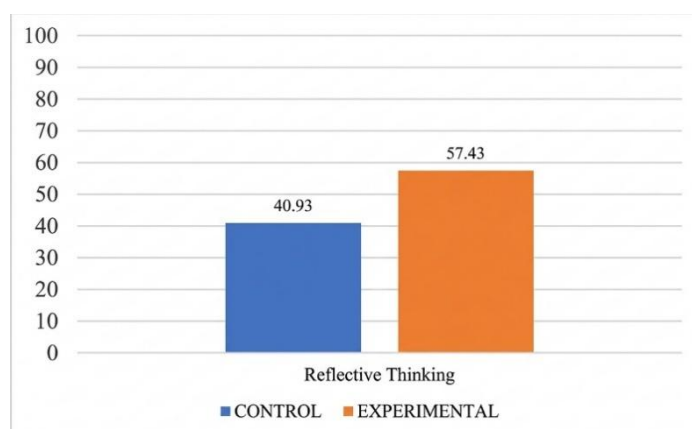


Figure 1. Differences in reflective thinking skills in the experimental and control classes

The significant difference between the control and experimental classes indicates that *the Socio-Scientific Issues -based electronic module* on ecosystems can improve students' reflective thinking skills. The improvement in reflective thinking skills is shown in Table 17.

Table 17. Improvement of students' reflective thinking skills

Class	Average		N-gain score	Category
	<i>Pretest</i>	<i>Posttest</i>		
Control	46.07	40.93	-0.09	Low
Experiment	46.18	57.43	0.21	Low

The effectiveness of SSI-based electronic modules on scientific argumentation skills

To determine whether both classes had the same initial abilities, a hypothesis test was conducted on the *pretest data* for scientific argumentation ability. The results of *the pretest data* normality test are shown in Table 18.

Table 18. Results of the pretest data normality test

Class		Shapiro-Wilk		
		Statistics	df	Sig.
Scientific	Control	.674	28	<.001
Argumentation	Experiment	.793	28	<.001

The significance value is less than 0.05, so it can be concluded that the *pretest data* on students' scientific argumentation skills in both classes are not normally distributed. Next, a homogeneity test was conducted, as shown in Table 19.

Table 19. Homogeneity test of scientific argumentation pretest data

		Levene Statistics	df1	df2	Sig.
Scientific	Based on mean	.000	1	54	.988
Argumentation	Based on Median	.106	1	54	.746
	Based on Median with adjusted df	.106	1	52.03	.746
	Based on trimmed mean	.059	1	54	.809

These results indicate that the variance of *the pretest data* in the control and experimental classes is homogeneous. Based on the results of normality and homogeneity tests

above, the data on students' scientific argumentation abilities were analyzed using the Mann-Whitney test. The results of the Mann-Whitney test on students' scientific argumentation data are presented in Table 20.

Table 20. Results of the Mann-Whitney hypothesis test of scientific argumentation ability pretest data

Scientific Argumentation	
Mann-Whitney University	175,000
Wilcoxon W	581,000
Z	-3,828
Asymp. Sig. (2-tailed)	<.001

Based on Table 20, there is a significant difference in students' initial scientific argumentation abilities between the control and experimental classes. Furthermore, to test the effectiveness of the developed electronic module, a hypothesis test was conducted on the *posttest data* on students' scientific argumentation abilities. A description of the scientific argumentation ability data is presented in Table 21.

Table 21. Descriptive results of scientific argumentation ability data

No	Information	Scientific Argumentation			
		Control Class		Experimental Class	
		<i>Pretest</i>	<i>Posttest</i>	<i>Pretest</i>	<i>Posttest</i>
1	Minimum	17	17	17	17
2	Maximum	50	50	50	83
3	Mean	23.93	25.68	36.18	47.07
4	Std Deviation	10,331	11,324	11,126	17,003

Pretest results showed that the control and experimental classes had different initial abilities. These differences necessitated separate analyses of improvement for each class. Before determining which parametric or nonparametric statistics to use, it was necessary to test the normality of the pretest and posttest data for each class. The results of the normality test for the pretest and posttest data for the control class are shown in Table 22.

Table 22. Results of the normality test for the pretest and posttest of scientific argumentation in the control class

		Shapiro-Wilk		
Test		Statistics	df	Sig.
Scientific Argumentation	Pretest	.674	28	<.001
	Posttest	.722	28	<.001

It can be concluded that the pretest and posttest data for the control class were not normally distributed. Further analysis to test for pretest-posttest improvement in the control class was conducted using the nonparametric Wilcoxon Signed-Rank Test. The results of the Wilcoxon Signed Rank Test are presented in Table 23.

Table 23. Results of the Wilcoxon Signed Rank Test for the Control Class

Test Statistics	
Z	-.775 ^b
Asymp. Sig. (2-tailed)	.439

It can be concluded that there was no significant difference between the pretest and posttest scores in the control class. Next, a normality test was conducted on the pretest and posttest data in the experimental class. The results of the normality test are presented in Table 24.

Table 24. Results of the normality test for the pretest and posttest of scientific argumentation in the experimental class

	Test	Shapiro-Wilk		
		Statistics	df	Sig.
Scientific	Pretest	.793	28	<.001
Argumentation	Posttest	.881	28	.004

It can be concluded that the *pretest* and *posttest* data on scientific argumentation skills in the experimental class were not normally distributed. Further analysis was conducted using the nonparametric Wilcoxon Signed-Rank Test. The results of the Wilcoxon Signed Rank Test are presented in Table 25.

Table 25. Results of the Wilcoxon signed rank test for the experimental class

Test Statistics	
Z	-3.114 ^b
Asymp. Sig. (2-tailed)	.002

It can be concluded that there is a significant difference between the *pretest* and *posttest* scores of students' scientific argumentation skills in the experimental class. This indicates that after using the SSI-based electronic module, students' scientific argumentation skills increased significantly. The difference in scientific argumentation skills between students in the control and experimental classes after using the SSI-based electronic module is shown in the following figure (Figure 2).

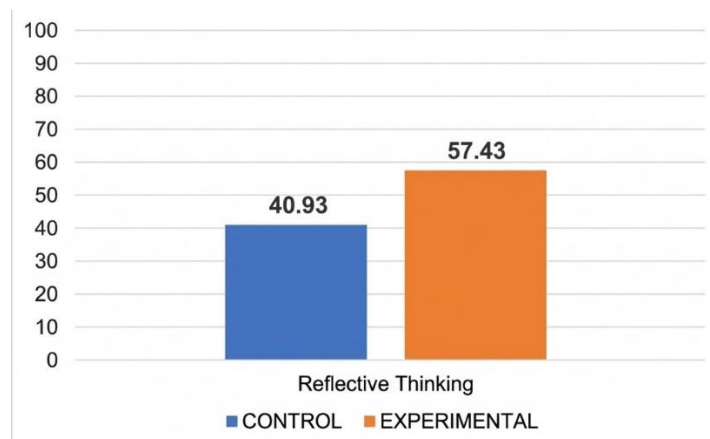


Figure 2. Differences in posttest data on scientific argumentation ability between the control class and the experimental class

The significant difference between the control and experimental classes indicates that the SSI-based electronic module on ecosystems can improve students' scientific argumentation skills. The improvement in scientific argumentation skills is shown in Table 26.

Table 26. Improvement of students' scientific argumentation skills

Class	Average		N-gain score	Category
	Pretest	Posttest		
Control	23.93	25.68	0.02	Low
Experiment	36.18	47.07	0.17	Low

Discussion

Feasibility and practicality of electronic modules

The electronic module development process conducted in this study produced a final product suitable for use in biology education. Product feasibility was determined through a

series of validation stages by material experts and media experts, followed by practicality testing by biology teachers and readability testing by students. These stages were carried out to ensure that the developed module was not only conceptually sound but also easy to use in the learning process.

Based on the results of the material expert validation, the conceptual accuracy of the material in the electronic module reached 98%, indicating that most of the concepts presented align with correct biological concepts. However, several improvements were made based on suggestions and input from the material experts to ensure the presentation of concepts was more precise and easier for students to understand. Furthermore, the module's feasibility assessment results, based on the aspects of material, evaluation, language, and presentation, achieved an average percentage of 92%, categorized as very suitable. These results indicate that the material content, evaluation structure, language use, and module presentation meet the criteria for suitability as a teaching material.

The module's feasibility was further strengthened by the results of the media expert validation, which assessed aspects of design/graphics, presentation, display and language, and ease of use. The assessment results showed that all aspects achieved a 100% score, categorized as very feasible. This indicates that the electronic module's display has been designed to be attractive, systematic, and user-friendly, thereby supporting student engagement in the learning process. After revisions based on expert advice, the electronic module was then tested for practicality through assessments by biology teachers. The teacher assessment results showed that the module achieved an average percentage of 86%, categorized as very feasible. This indicates that the developed module is considered practical for learning, in terms of material suitability, evaluation presentation, language use, and module display design.

The module's practicality was also supported by the results of a student readability test. Student responses indicated that the electronic module received an average score of 85%, categorized as very appropriate. These results indicate that the module's material is easy to understand, its presentation is engaging, and the visuals and language used assist students in independent study. Furthermore, the module was deemed capable of encouraging independent learning in understanding ecosystem concepts.

Based on the development process, from expert validation and product revision to practicality testing by teachers and students, it can be concluded that the developed electronic module meets the eligibility and practicality criteria. Therefore, the developed socioscientific issue-based electronic module can be used as a teaching material to support biology learning. The next stage is the implementation of the electronic module in a limited-scale field trial to determine its effectiveness in improving students' reflective thinking and scientific argumentation skills.

Effectiveness of electronic modules

The effectiveness of SSI-based electronic modules on reflective thinking skills

Learning in the control class used conventional strategies, with the Campbell Biology textbook as the primary source. Students were asked to read the material and then rewrite the information obtained to reinforce conceptual understanding. The learning continued with a group project involving observations of ecosystems in the surrounding environment. The results of these observations were compiled and presented to the class for reporting and discussion of learning outcomes.

Unlike the control class, the experimental class used an electronic module based on Socio-Scientific Issues (SSI). This module was designed to encourage active student engagement through the analysis of contextual problems related to real-life ecosystems. Students were guided to reflect on the information, consider various perspectives, and relate

biological concepts to real-life situations. Therefore, the SSI-based electronic module was expected to improve students' reflective thinking skills compared to conventional learning.

The improvement in reflective thinking skills was measured using pre- and post-test essay tests. The pre-test results showed no significant differences between the control and experimental classes, and the data were normally distributed and homogeneous. This indicates that both classes had relatively equal initial abilities, so the difference in final results can be attributed to the use of the electronic module.

The post-test results showed a significant difference between the two classes. Because the data variance was not homogeneous, the hypothesis was tested using the Mann-Whitney U test with a significance value <0.05 . These results indicate that the use of electronic modules affects students' reflective thinking skills. Students in the experimental class achieved better results than the control class, suggesting that learning with electronic modules provides a more meaningful learning experience and encourages deeper thinking.

Based on the n-gain results, the control class only experienced a low level of improvement. This indicates that learning without electronic modules has not facilitated the optimal development of reflective thinking skills. Students tend to passively receive information without conducting in-depth analysis or evaluation. This finding aligns with research by [Fadillah et al. \(2024\)](#), which states that conventional learning has limitations in developing higher-order thinking skills, such as reflective thinking, because students are less involved in problem-solving and in reflecting on learning. As a result, students tend to stop at the initial stage of reacting without reaching the stages of comparing and contemplating.

In contrast, the experimental class showed an increase in reflective thinking skills, although it did not reach the moderate category. This indicates that the electronic module made a positive contribution to the development of students' reflective thinking skills. This finding aligns with research by [Fatma et al. \(2025\)](#), which states that developments in information technology encourage innovation in digital learning media, including the use of electronic modules in biology lessons. The SSI-based electronic module presents contextual problems, provocative questions, and activities that encourage students to reflect on the knowledge they have acquired. Theoretically, reflective thinking skills can be explained by [Titus & Muttungal's \(2024\)](#) theory, which divides the reflection process into three stages: reacting, comparing, and contemplating. The reacting stage is the initial response to a problem; the comparing stage involves comparing with previous experience or knowledge; while the contemplating stage is a critical evaluation process that produces new understanding. The results of the study indicate that students are still in the adaptation stage to learning that requires deeper reflection.

The improvement in the experimental class was influenced by the characteristics of the electronic module, which included thought-provoking questions, case studies, and analytical activities that encouraged students to consider the reasons behind phenomena. These activities indirectly trained students in critical and reflective thinking. Furthermore, the electronic module supported students' independent learning and provided flexible access to materials, thereby fostering a deeper understanding of concepts.

However, the improvement that did not reach the moderate category indicates that the module's effectiveness remains influenced by several factors, including the relatively short treatment duration. Reflective thinking skills are high-level skills that require continuous practice ([Hammad Al-Rashidi & Aberash, 2024](#)). Furthermore, students' study habits, previously more memorization-oriented learning, also influence the adaptation process to reflection-based learning ([Kaplan et al., 2023](#)). This aligns with [Sadler's \(2011\)](#) opinion, which states that students are often unfamiliar with SSI-based learning and require time to fully understand issues and concepts. Overall, the results of this study support previous findings that Socio-Scientific Issues-based learning materials can improve students' reflective thinking

skills. Research by [Alvita & Wasis \(2017\)](#) shows that SSI-based learning can improve students' reflective judgment from a pre-reflective level.

The effectiveness of SSI-based electronic modules on scientific argumentation skills

Pretest results showed differences in students' initial scientific argumentation skills between the control and experimental classes. The experimental class's pretest average was higher, possibly influenced by prior learning experiences, motivation, or a more supportive learning environment. This difference in initial abilities may influence how quickly students adapt to electronic modules and to scientific argumentation-based learning.

Posttest results showed that the control class did not experience significant improvement, while the experimental class did. This suggests that the Socio-Scientific Issues (SSI)-based electronic module positively contributes to students' scientific argumentation skills by providing opportunities to analyze information, compare evidence, and systematically construct claims and reasons. The module also presents an SSI context that encourages students to consider multiple perspectives in constructing arguments, from claims to qualifiers. This finding aligns with [Toulmin's \(2012\)](#) argumentation framework, which emphasizes the interconnectedness of claims, data, warrants, backing, rebuttals, and qualifiers.

In the experimental class, during the pretest, most students were only able to construct claims and data, with a small number including warrants. After learning with the SSI-based electronic module, students were able to add backing and rebuttal. Although the improvement was significant, the n-gain value was still below the moderate category. This was influenced by the limited time spent using the module, students' lack of familiarity with scientific argumentation, and the complexity of the ecosystem material, which requires in-depth conceptual understanding. This condition is consistent with research by [Riwayani et al. \(2019\)](#), which found that students often have difficulty constructing arguments grounded in scientific concepts and do not fully understand the components of argumentation. In addition, limited use of data to support claims ([Sampson & Clark, 2011](#)) and the use of reasons or rebuttals that are not yet understood ([Steinkuehler & Duncan, 2008](#)) also contribute to the low quality of argumentation. Research by [Olii et al. \(2025\)](#) also shows that low-quality argumentation is related to a lack of conceptual understanding of the material.

Based on the results of this study, the experimental class showed clearer improvements than the control class in several argumentation components, particularly warrant, backing, and rebuttal. This occurred because the activities in the electronic module required students to include scientific evidence and reasoning to support their claims and to relate information to relevant biological concepts. Meanwhile, the claim and data components remained high because students were accustomed to presenting conclusions in previous lessons ([McNeill & Krajcik, 2011](#)). However, improvements in warrant, backing, rebuttal, and especially qualifier remained low. The rebuttal and qualifier components are often difficult to develop because they require a strong conceptual understanding and the ability to critically evaluate arguments ([Muna & Rusmini, 2021](#)). Furthermore, teacher-centered learning habits often require students to provide correct answers rather than evaluate various possible arguments ([Karlina & Alberida, 2021](#)).

In contrast, in the control class, the claim component remained relatively stable, but the data did not show significant improvement. This suggests that conventional learning, which focuses on delivering material, has not encouraged students to actively use scientific evidence when constructing arguments. Although there was a slight increase in warrants, the results remained lower than those in the experimental class. This indicates that traditional learning methods have limited influence on the development of the structure of scientific argumentation. Students tend to struggle to formulate warrants because they are not accustomed to providing detailed explanations and are instead directed toward memorizing the material ([Roja et al.,](#)

2020). Overall, students' scientific argumentation skills are influenced by their conceptual understanding and the learning strategies used. In the control class, learning about ecosystems was dominated by teacher-centered discussion and lecture methods, which did not enhance students' confidence in argumentation. Therefore, teachers need to design learning tools that can enhance the quality of students' argumentation (Suartha et al., 2020).

CONCLUSION

The developed Socio-Scientific Issues (SSI) based electronic module has proven to be very feasible, practical, and effective for use in learning because it has been validated by experts, received positive responses from teachers and students, and is able to improve students' reflective thinking and scientific argumentation skills, although the improvement is still limited due to the short duration of use and a learning culture that previously tended to be teacher-centered and memorization-based. The implications of these findings indicate that the integration of socio-scientific issues in digital media has the potential to break through conventional learning patterns towards critical thinking, so that for further research it is recommended to extend the duration of module implementation, combine it with active learning models such as Problem-Based Learning, and expand the scope of socio-scientific issue topics to optimize students' conceptual understanding and thinking skills.

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