Tersedia online di EDUSAINS
Website: http://journal.uinjkt.ac.id/index.php/edusains

EDUSAINS, 17 (2), 2025, 120-133

Research Artikel

THE EFFECTIVENESS OF SOCIO-SCIENTIFIC ISSUE-BASED ELECTRONIC MODULES ON SENIOR HIGH SCHOOL STUDENTS' ARGUMENTATION SKILLS AND PERCEPTIONS OF BIOTECHNOLOGY

Fitri Husni Mardiyah[1*], Widi Purwianingsih[2], Rini Solihat[3]
[1,2,3]Indonesia University of Education, Bandung, Indonesia
fitrihusni@upi.edu[1*]

Abstract

Argumentation abilities can be developed using electronic modules based on socio-scientific issue themes in biotechnology materials. The purpose of this project is to gather data regarding the efficacy of using electronic modules centered on socio-scientific issues to enhance students' perceptions of biotechnology and their ability to argue. A quasi-experimental approach was taken in this investigation. The non-equivalent control group design is the research methodology employed. The sample consisted of 120 students from Class XII who were selected with the purposive sampling technique. The experimental group was taught using a socio-scientific issue-based electronic module integrated with a problem-based learning model, whole the control group received instruction using a conventional electronic module without socio-scientific issue integration. The findings demonstrated that there was a significant average difference in argumentation skills between the experimental and control classes. The results of the Mann-Whitney test on the value of argumentation skills indicate that there is a difference in the effectiveness of utilizing regular modules to increase students' argumentation abilities against electronic modules based on socio-scientific issue issues is 0.002 (2-tailed = 0.002) < (0.05). The findings indicated that the average difference between the experimental class and the control class was significant in students' perceptions of biotechnology. The findings demonstrated that students' perceptions of biotechnology differed significantly on average across the experimental and control classes. According to the results of the Mann-Whitney test on the value of students' perceptions of biotechnology, the effectiveness of using electronic modules based on socio-scientific issue issues differs from that of regular modules in terms of improving students' perceptions of biotechnology is 0.003 (2-tailed = 0.003) < (0.05). The N-Gain score requirements for enhancing students' reasoning skills through the use of electronic modules centered on socio-scientific issue topics.

Keywords: *Argumentation skills, biotechnology, electronic module, socio-scientific issue, students' perceptions of biotechnology*

***Permalink/*DOI:** https://doi.org/10.15408/es.v17i2.48908

How To Cite: Mardiyah, F. H., Purwianingsih, W., Solihat, R., A. (2025). The Effectiveness of Socio-Scientific Issue–Based Electronic Modules on Senior High School Students' Argumentation Skills and Perceptions of Biotechnology. *EDUSAINS*, 17 (2): 118-132.

*Corresponding author
Received: 17 November 2025; Revised: 22-29 December 2025; Accepted: 30 December 2025
EDUSAINS, p-ISSN 1979-7281 e-ISSN 2443-1281

INTRODUCTION

The field of education continues to undergo changes and developments to shape the next generation of the nation as quality human resources with various skills (Wüstenberg et al., 2014). The skills that must be imparted to students among communication skills, problem-solving, creativity, critical thinking, and collaboration are critical thinking skills. Argumentation skills are part of the critical thinking skills process that explain reasoning and enhance students' ability to assess credible information (Hanegan & Bigler, 2009). Argumentation skills lie at the intersection of creative thinking skills and critical thinking skills; both skills can be honed through argumentation skills (Glassner & Schwarz, 2007).

According to previous research, students' argumentation skills are categorized as very poor, with low average scores in argumentation skills, particularly in biotechnology material. This can be caused by various factors in the learning process, including less innovative teaching methods and the lack of habituation for students to express their opinions (Bögeholz et al., 2017). So far, students are rarely trained in argumentation skills, and they are seldom invited to discuss or debate during the classroom learning process. Students' argumentation skills need to be trained so that they can meet these challenges and analyze problems related to science or knowledge based on existing evidence and facts.

Discussion activities that address socio-scientific issues are one way for students to present their arguments because these discussions provide a problem to be debated, allowing students to make decisions (Chu et al., 2017). Socio-scientific issue issues-based learning can improve 21st-century abilities like problem-solving (Zamakhsyari & Rahayu, 2020) critical thinking (Pratiwi et al., 2016), decision-making, and argumentation (Purwati et al., 2019). Students can use life experiences, moral principles, and scientific data to support their arguments in this setting (Chowdhury et al., 2020).

One of the subjects in biology that can equip students with critical thinking skills is biotechnology, and one of the skills that can be imparted is argumentation skills. In addition, biotechnology is a subject that has many socio-scientific issues. This is in line with Dawson and Venville (2009) who state that this is because the topic of biotechnology is too controversial as it generally not only contains scientific content but also socio-scientific issues in the form of economic, social, and political aspects.

Research worldwide has revealed that students still have limited knowledge and negative attitudes towards biotechnology (Sáez et al., 2008). Therefore, a study is needed to measure students' understanding of the factors that influence their perceptions of biotechnology. Students' perceptions of an issue are a comprehensive assessment of the impact, utility, and limitations of biotechnology and are influenced by the interaction between knowledge, attitudes, and motivation, particularly interest and enthusiasm for the subject matter (Fonseca et al., 2012a).

Students' skills in argumentation can lead to better understanding and perceptions of biotechnology, thereby influencing learning and academic achievement (Kaya et al., 2010). Based on the results of previous studies, there is a need for learning support tools that can enhance students' argumentation skills based on socio-scientific issues and students' perceptions of biotechnology. A module is one of the learning assistance resources. Modules are educational materials that cover a variety of subjects, are arranged according to instructional design, and are given to students to utilize in class activities (Kemdikbud, 2020). To improve reasoning abilities and attitudes towards biotechnology, modules must be developed in conjunction with the application of learning methodologies or models (Irwan et al., 2019).

Innovation or adjustments need to be made to address the issues of limited time and available books at school, one of which is through certain media that assist in the learning process, namely electronic modules. In this electronic module, students can access it flexibly without being bound by place and time (Tekin et al., 2020).

The characteristics of electronic modules are e-modules are designed to be self-instructional, allowing students to learn independently without constant teacher intervention (Banjer et al., 2021). E-modules leverage technology to provide continuous learning opportunities without space and time limitations, this includes the use of videos, animations, links to various sources, and formative tests (Nuraini & Ronoatmodjo, 2018). The development of e-modules often involves rigorous validation processes by experts to ensure their effectiveness and feasibility (Banjer et al., 2021). This can address issues in distance learning. The form of innovation in the development of electronic modules in learning is the module based on problem-based learning (PBL) (Saifuddin et al., 2020). The problem-based learning model is used to encourage students to enhance their higher-order thinking processes. Therefore, the biotechnology module based on socio-scientific issues integrated with PBL has the potential to activate argumentation skills.

METHOD

This study's quasi-experimental research design uses a non-equivalent control group design type.. This research design was chosen because it relates to the objective of this study, which is to determine the effectiveness of an electronic module based on socio-scientific issues in improving students' argumentation skills and their perception of biotechnology. Two classes were the subject of the study: the experimental class, which used electronic modules for learning based on socio-scientific issue concerns utilising a problem-based learning approach, and the control class, which used modules without any socio-scientific issue issue. The determination of subjects was conducted through purposive sampling, which involved selecting 12th-grade students who met the criteria of having adequate devices or smartphones capable of downloading electronic modules and who had not yet covered biotechnology material at the high school level.

The population in this study consists of 12th-grade students, totaling 120 students from one of the high schools in West Bandung Regency. The sample was selected using a purposive sampling technique, in this study consists of two classes that will become the control class and the experimental class. Students in the experimental class who were given treatment with an electronic module based on ocio-scientific issues consisted of 60 students, and the control class also consisted of 60 students.

A perception questionnaire and an argumentation rubric were the research tools utilized. Toulmin's theoretical framework served as the foundation for the development of the argumentation rubric, which measures the quality of students' argumentation using the elements of claim, data, warrant, backing, qualifier, and rebuttal. This allows for the systematic and objective measurement of argumentation. The perception questionnaire was also used to gauge how students felt about the material they were learning and the subject they were studying. Twenty statement items covering interest, comprehension, material relevance, and students' attitudes toward the learning process and the topic under study were included in the Likert scale format.

Expert judgement, or the evaluation by professionals with expertise in biology education and learning assessment, was used to determine the validity of the instrument in this study by ensuring that each statement item was appropriate for the construct being measured. The instrument's degree of internal consistency was then ascertained by analyzing its reliability using Cronbach's Alpha coefficient. The 20 statement items have high reliability, according to the analysis results, which revealed a Cronbach's Alpha value of 0.822. As a result, the instrument was deemed adequately dependable, consistent, and appropriate for use in the research.

The e-module's Problem-Based Learning (PBL) phases start with Problem Analysis and Learning Issues, where students analyze contextual issues and identify learning problems that require further investigation. The following phase is called Discovery and Reporting, during which students investigate topics, gather information, and present their conclusions as the foundation for creating solutions. The learning process ends with reflection to assess the method, outcomes, and knowledge acquired. Next, in the Solution Presentation stage, students present their developed solutions along with supporting arguments.

RESULTS AND DISCUSSION

In this section, the findings and discussion are presented. The class utilising an electronic module based on socio-scientific issues and the control class using a conventional electronic module (not based on socio-scientific issues) differed in their ability to argue, as explained in the first section. The second section describes how the class that used electronic modules based on socio-scientific issue concerns and the control class that used conventional electronic modules (not based on socio-scientific issue issues) differed in how the students saw biotechnology.

The following presents the findings related to students' argumentation skills. The Mann Whitney U Test, normality tests, and homogeneity tests were used to examine the differences in reasoning skills data between the experimental and control classes. Table 1 displays the findings of the statistical data analysis.

Table 1. Statistical Analysis of Pre-test Results on Differences in Students' Argumentation Skills

Data Type		***Pretest***	
Group		**Control**	**Experiment**
N		60	60
Mean		2.23	2.43
Standard Deviation		0.767	0.871
Test of Normality (Kolmogorov -Smirnov)	Sig.	0.000	0.000
	Inter	Not normal	
Test of Homogenity (Levene's Test)	Sig.	0.176	
	Inter	Not homogenous	
Mann Whitney U Test	Sig.	0.186	
	Inter	Not Significant	

Based on the average of the experimental and control classes, the argumentation level of students in the pretest was 2.23 out of a maximum score of 5 for the experimental class and 2.43 out of a maximum score of 5 for the control class. It can be seen that the students' level of argumentation is level 2, which means arguments with supporting data but no counterclaims. This is consistent with research at higher levels, which is dominated by level 2, although some reach level 3. The dominance of argumentation skills at Level 2 may be influenced by cognitive development at higher levels during the formal operational phase. At this stage, high school students can discuss alternative viewpoints on issues or provide ideas or suggestions that they believe will help guide the discussion on the problems identified in the research (Amalia & Kustijono, 2017).

After completing the pretest, students received an experimental educational module using an electronic module based on socio-scientific issues, while the control class used a regular electronic module. After completing the learning, the students were retested and given a posttest. The results of the post-test analysis are shown in Table 2.

According to Table 1 and 2, the experimental class that used an electronic module to learn about socio-scientific issue concerns often improved their scores more than the control class that also used an electronic module. In the experimental class, the difference in score improvement between the final test (post-test) and the first test (pre-test) is 0.62, whereas in control class, the difference in score improvement between the final test (post-test) and the first test (pre-test) is 0.17.

Table 2. Statistical Analysis of Post-test Results on Differences in Students' Argumentation Skills

Data Type		***Posttest***	
Group		**Control**	**Experiment**
N		60	60
Mean		2.40	3.05
Standard Deviation		0.741	1.171
Test of Normality (Kolmogorov-Smirnov)	Sig.	0.000	0.000
	Inter	Not Normal	
Test of Homogenity (Levene's Test)	Sig.	0.004	
	Inter	Homogenous	
Mann Whitney U	Sig.	0.002	
	Inter	Significant	

The difference in the pretest–posttest gain between the experimental class, and the control class is also presented in Figure 1.

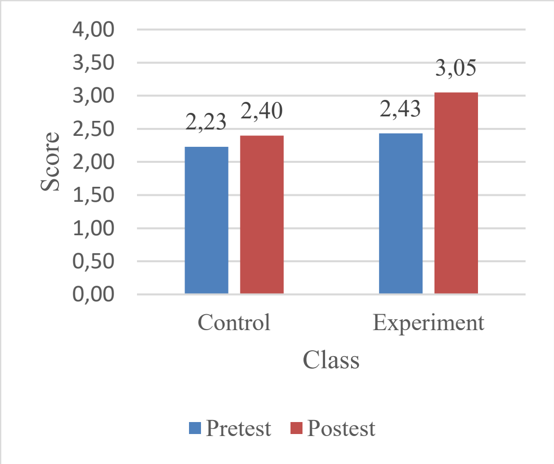

Figure 1. The pre-test and post-test results

In the post-test data, the average level of inference achieved in the experimental class was higher than the average achieved in the control class. Students who studied socio-scientific issues in the electronic module achieved better results at the reasoning level of 3.05 than students in the control class at the reasoning level of 2.40.

This is consistent with the findings of Sadler and Zeidler (2005) that a socio-scientific issue-based learning environment involves students in independent scientific learning, reasoning, and moral reasoning. When faced with social science issues, students raise controversial social science problems (Sadler, 2004). The socio-scientific issues discussed are closely related to contextual life, making it easier for students to discuss.

The increase in the level of discussion in experimental education can also be caused by the content or materials used, namely biotechnology issues. Biotechnology is one of the concepts in biology that can test students' critical thinking abilities, and one of the skills that can be enhanced is reasoning ability (Christenson et al., 2017). In addition, biotechnology is full of social science issues. This is in line with the statement by (Dawson & Venville, 2013) that the topic of biotechnology generally is not only scientific but also involves social science issues in the form of social, economic, and political dimensions. Often controversial in the field of new science and technology.

A meaningful learning environment that encourages students to use their argumentation abilities is provided by educational media with electronic modules centred on socio-scientific issue topics (Jho et al., 2014). One of the outcomes of socio-scientific issue-based learning is the improvement of students' argumentation skills by applying their skills in debating, critiquing, discussing, and negotiating based on evidence (Eggert et al., 2017).

According to Norris and Phillips (2003), in a socio-scientific issue-based setting, students can integrate and apply their knowledge of science content and fundamental science literacy skills (i.e., the capacity to read and write science texts and various styles of representation). As they collaborate and apply their knowledge of arguments to a scientific problem or topic, students in this setting provide a variety of ideas in order to develop their argumentation skills. In other words, students are expected to debate, discuss, defend, and eradicate biases using their knowledge of what constitutes strong evidence and strong statements in such a setting (Yapıcıoğlu, 2018).

Students may be able to engage in debate in two significant ways through the usage of electronic modules centred on socio-scientific issue topics: (1) Social negotiation: students can debate, defend, and remove biases in arguments to reach an agreement; and (2) epistemic understanding of arguments: students learn what makes an argument strong and can use that knowledge to inform and critique others (Chen et al., 2016).

The difference in achievement scores between the experimental class and the control class is influenced by the learning media used. This is consistent with the findings of Iordanou and Constantinou (2015) who claimed that students may formulate arguments for debates, present them for public review, and then amend them after learning about their advantages and disadvantages. Students improve their arguments and make better conclusions as a result of the construction and critique process. Socio-scientific issue argumentation exercises help students understand how society makes well-informed decisions on socio-scientific issue issues and involve them in the decision-making process with evidence support.

The electronic module-based learning media on socio-scientific issues used in education, such as Zoom, Google Meet, WhatsApp, academic portals, and others, have limitations due to unstable internet connections (Wahidah et al., 2018). This is supported by research showing that electronic learning media modules based on socio-scientific issues are very helpful for students, as they do not require an internet package, are not limited by unstable internet connections, and can be operated by students anywhere (Iordanou & Constantinou, 2015).

Teaching methods and learning media need to be integrated based on learning materials. One form of integration in this research is the development of electronic modules based on socio-scientific issues. The electronic module becomes a solution to facilitate the learning of material for students. This is in line with survey findings that 100% of students are interested in participating in multimedia-enhanced learning. Learning using smartphones can support more active learning without being constrained by time and place. (Larasati, 2019). The learning experience provided to students through mobile and innovative technology is equipped with personalized content and learning pathways to enhance higher-order skills and facilitate independent learning (Amalia & Kustijono, 2017).

Furthermore, the study's findings indicate that students in the biotechnology course they are enrolled in employ electronic modules related to tissue culture, animal cloning, recombinant DNA, hybridoma technology, and in vitro fertilisation. Since the use of biotechnology has a big influence on society, the community is involved in decision-making and takes a critical position towards its application (Fonseca et al., 2012b).

According to Kolarova (2011), students between the ages of 15 and 19 who get modern biotechnology instruction can be inspired to make choices and develop a critical mindset regarding the use of contemporary biotechnology in society. Khishfe (2012) gave pupils the task of debating and making decisions regarding genetically modified organisms (GMOs) and animal cloning. There are many biotechnology topics that can be addressed in Indonesia, such as issues related to biotechnology in the fields of agriculture, health, and genetic engineering.

The assessment of argumentation skills is used to obtain N-gain test results. The results obtained come from the pre-test and post-test results in the control class and the experimental class. During the learning and research period, the control class used a regular electronic module, while the experimental class used an electronic module based on socio-scientific issues. Based on the N-gain calculations, the conclusions from the pre-test and post-test calculations are presented in Table 3.

Tabel 3. N-gain Results Argumentation Skills Pre-test and Post-test Control and Experimental Classes

Group	**Score**		**Gain**	**N-gain**	**N-gain percent (%)**	**Desc**
	Pretest	***Posttest***				
Control	44.67	48.00	3.33	0.00	0	Low
Experiment	48.67	61.00	12.33	0.31	31	Intermediate

Based on the results of the N-gain percent test calculations in Table 3, it shows that the average N-gain percent for the experimental class (learning using electronic modules based on socio-scientific issues) is 31%, which falls into the ineffective category. In contrast, the control class (which uses electronic modules that are not grounded in socio-scientific issues) has an average N-gain percentage of 0%, placing it in the category of extremely ineffectual. As a result, using electronic modules that focus on socio-scientific issue topics does not help students become better argumentators. In the meantime, students' ability to argue is not greatly enhanced by the usage of electronic modules that are not grounded in socio-scientific issue topics.

Although the Mann–Whitney U test indicated a statistically significant difference, the N-gain results suggest that the magnitude of improvement was relatively low. The relatively low N-gain may be attributed to several factors, including the short duration of the intervention, which limited students' opportunities to deeply engage with the learning process. In addition, students were not yet accustomed to learning through socioscientific issues (SSI), requiring an adaptation period to effectively develop higher-order thinking and argumentation skills. The implementation of discussions in a predominantly online setting also constrained interaction, collaboration, and depth of exchange among students. Furthermore, the learning process tended to emphasize cognitive aspects more strongly than affective components, which may have reduced students' emotional engagement and personal connection with the issues discussed.

The application of socio-scientific issue issues for classroom learning provides a meaningful learning environment for students to enhance their reasoning skills (Jho et al., 2014). One of the outcomes of socio-scientific issue-based learning is the improvement of students' argumentation skills because the learning applies students' skills in debate, critique, discussion, and negotiation based on evidence (Eggert et al., 2017). As they collaborate and use their epistemic understanding of arguments on a scientific issue or topic, students in his socio-scientific issue-based environment provide a variety of ideas to develop their argumentation skills. This implies that students are encouraged to argue, defend, debate, and discuss while having a clear understanding of what constitutes strong evidence and a strong claim in this setting (Yapıcıoğlu, 2018).

Two significant aspects of socio-scientific issue issues can offer students an argumentative environment: (1) social negotiation, where students can discuss, defend, and eliminate argument biases; and (2) epistemic understanding of arguments, where students can gain a deeper understanding of what constitutes a good dispute and use this understanding to inform and critique others (Chen et al., 2016).

Students can develop arguments and share their opinions during discussion or problem-solving activities that have been incorporated with PBL learning in the module, especially in the socio-scientific issue feature. They can then receive feedback from their peers to understand the arguments' strengths and weaknesses and make improvements (Bathgate et al., 2015). Better decisions and stronger arguments can result from the process. Due to the evidence-based support and the improved comprehension of the information presented in socio-scientific issue issues, discussion activities that develop argumentation skills using socio-scientific issue issues can have an impact on students' decision-making (Lindahl & Lundin, 2016). Therefore, the goal of discussion exercises involving socio-scientific issue topics is not only to foster friendships with people who hold different views and accept arguments, but also to arrive at a judgement that is accepted by both parties through debate and analysis of the available data (Hancock et al., 2019).

The students' perceptions referred to in this study consist of several indicators, namely attitude, the importance of biotechnology, and interest in biotechnology. The attitude section is assessed on a four-point Likert scale. The way to measure students' perceptions of biotechnology is by using a questionnaire given to the students. The aspects discussed regarding students' perceptions of biotechnology include statistical analysis, students' perceptions per indicator such as the importance of biotechnology, cognitive, affective, behavioral, interest in biotechnology, and interest in an activity related to biotechnology (Klop & Severiens, 2007), gain and N-gain analysis, and the significance test of students' perceptions of biotechnology in the experimental class and the control class. The results of the statistical data analysis can be seen in Table 4.

Table 4. Data Analysis of Pre-test Results of Student Perception Questionnaire on Biotechnology

Group		***Pretest***	
Data Type		**Control**	**Experiment**
N		60	60
Mean		60.18	56.05
Test of Normality (Kolmogorov-Smirnov)	Sig.	0.200	0.005
	Inter	Normal	Normal
Test of Homogenity	Sig.	0.015	
	Inter	Homogenous	

Group		Pretest	
Data Type		Control	Experiment
(*Levene's Test)*			
Mann Whitney U test	Sig.	0.017	
	Inter	Significant	

Based on the research findings in Table 4, the pre-test scores differ significantly, indicating that the control and experimental class students have different levels of perception about biotechnology before the learning process. The normality test on the experimental class and the control class showed normal results for the control class, while the experimental class showed non-normal data, and the homogeneity test indicated non-homogeneous results in the pre-test. There is a difference between the average students' perceptions of biotechnology in the experimental and control classes. The experimental class's average is 60.18, whereas the control class's is 56.05. Next, the average comparison test using the Mann Whitney U test was conducted to determine the difference between the control class and the experimental class in the pre-test results. The results of the Mann Whitney U test reveal that the pre-test results between the experimental class and the control class have considerable argumentation skills. Therefore, the next step is to statistically analyze the data using gain or the difference between the post-test and pre-test data. The gain analysis data of the student perception questionnaire about biotechnology can be seen in Table 5.

Table 5. Data Analysis of Post-test Results of Student Perception Questionnaire on Biotechnology

Group		Postest	
Data Type		Control	Experiment
N		60	60
Mean		4.7	9.8
Test of Normality (Kolmogorov-Smirnov)	Sig.	0.003	0.000
	Inter	Normal	Normal
Test of Homogenity (Levene's Test)	Sig.	0.041	
	Inter	Homogenous	
Mann Whitney U test	Sig.	0.003	
	Inter	Significant	

Based on the research findings in Table 5, the normality test on the experimental class and the control class shows non-normal data results, and the homogeneity test shows non-homogeneous results in the gain test. The average gain in students' impression of biotechnology in the control class differs from the average perception of students in the experimental class, which is 9.8 for the experimental class and 4.7 for the control class. Next, the average comparison test utilising the Mann Whitney U test was undertaken to evaluate the difference between the control class and the experimental class in the pre-test data. The experimental class and the control class shown considerable gains in argumentation skills, according to the results of the Mann Whitney U test.

The Mann Whitney U test on students' perceptions of biotechnology after the learning was completed revealed a figure (2-tailed = 0.003) < α (0.05), which can be interpreted as significant. This indicates that there is a difference in the effectiveness of the control class and the experimental class, or that the use of regular electronic modules and socio-scientific issue-based electronic modules has a different effect on students' perceptions of biotechnology. Instead of being solely absorbed through books and texts, perceptions of biotechnology are anchored in the surrounding culture and portrayed as social science topics. This also supports the hypothesis (Hani & Mustapit, 2020) that although education plays an important role in public understanding, the goal of public perception of science cannot be achieved through education alone. Human cognition is influenced by cultural barriers (scientific culture), and the societal culture that elevates the modern education system has a significant impact on the level of human cognition.

These findings highlight the fact that students in the experimental class and those in the control class had different perspectives about biotechnology. Learning about biotechnology is integrated into the curriculum, and students seem to understand the content of biotechnology. However, the increase in biotechnology knowledge does not necessarily lead to a significant increase in the acceptance of biotechnology (Moreno-Guerrero et al., 2020). This is evidenced by the gain scores of the control and experimental classes, which were 4.7 and 9.8, respectively. That means the students' perception of biotechnology in the experimental class using the socio-scientific issue-based electronic module had a higher increase in perception compared to the students using the electronic module published by the Ministry of Education and Culture.

Developments in biotechnology bring up a number of ethical and societal concerns, as well as questions and uncertainties about possible hazards (Indriyani, 2019). Many experts in the field of science education agree that teaching biotechnology raises issues in the fields of politics, economics, ethics, and education. In order for students to comprehend these issues and be able to find the answers, they must obtain quality education as members of the next generation (Mohapatra et al., 2010). One of the earliest technologies in which the general public can engage in arguments on its use is biotechnology. The general public's perception of biotechnology is highly varied and difficult to generalise. Perceptions vary depending on factors like age, gender, education, culture, and the kind of biotechnology product (Črne-Hladnik et al., 2012).

The absence of conversation about the topic in schools is the cause of the disparity in perception. It is uncommon for biotechnology-related topics to be discussed in the classroom. Numerous educators possess the abilities and expertise required to facilitate class discussions on biotechnology-related topics, particularly the social, political, ethical, and economic facets of the topics under debate (Permana et al., 2016). The quantity of subjects in the science curriculum feels restrictive to other educators (Reis, 2004). It is also true that many scientific teachers avoid talking about the social, moral, and ethical ramifications of science and technology in the classroom because they see their work as fact-based instruction (Tal et al., 2019).

One of the most crucial elements in personal decision-making is the level of public interest in biotechnology products. Technology and risks can play a significant role in science literacy and education. For instance, according to Casanoves et al (2015) it is crucial to give students the chance to develop their own opinions about the advantages and disadvantages of contemporary biotechnology in addition to providing them with relevant content (Gardner & Jones, 2011).

Perceptions of biotechnology are rooted in the culture of the environment and are presented in the form of social science issues, not just absorbed through books and texts. This also supports the hypothesis (Hani & Mustapit, 2020) that although education plays an important role in public understanding, the goal of public perception of science cannot be achieved through education alone. Human cognition is influenced by cultural barriers (scientific culture), and the societal culture that elevates the modern education system has a significant impact on the level of human cognition.

These findings highlight the fact that students in the experimental class and those in the control class had different perspectives about biotechnology. Learning about biotechnology is integrated into the curriculum, and students seem to understand the content of biotechnology. However, the increase in biotechnology knowledge does not necessarily lead to an increase in recruitment (Moreno-Guerrero et al., 2020). This is evidenced by the gain scores of the control and experimental classes, which are 4.7 and 9.8, respectively. According to the Ministry of Education and Culture, this indicates that the students' understanding of biotechnology has increased in the experimental class that used an electronic module centred on socio-scientific themes.

The assessment of students' perceptions of biotechnology is used to obtain N-gain test results. The results obtained come from the pre-test and post-test results in the control class and the experimental class. The experimental class used an electronic module centred on socio-scientific themes during the learning and research period, while the control class used a standard electronic module. Based on the N-gain calculation, the conclusion of the pre-test and post-test calculations is presented in Table 6.

Table 6. N-gain Results of Student Perception About Biotechnology Pre-test and Post-test Control and Experimental Classes

Group	Score		N-gain	N-gain percent (%)	Desc
	Pretest	*Posttest*			
Control	60,18	64,88	0,07	7	Low
Experiment	56,05	65,85	0,21	21	Low

According to the results of the N-gain percent test calculations in Table 2.3, the experimental class (learning with electronic modules based on socio-scientific issues) had an average N-gain percent value of 21%, which is ineffective, while the control class (learning with electronic modules not based on socio-scientific issues) had an average N-gain percentage of 7%, which is very ineffective. This indicates that using electronic modules based on socio-scientific issues is ineffective in improving students' perceptions of biotechnology, while using electronic modules that are not based on socio-scientific issues is very ineffective.

This is supported by research that when individuals observe an object, the perception between one individual and another is likely to differ even though the observed object is the same. Responses to the perceived object can be either positive or negative (Jayanti & Arista, 2019). Even though the observed object is the same, each individual has a different perspective or viewpoint, resulting in differing perceptions (Walgito, 2015).

The reason for this difference in perception is the lack of discussion about this topic in schools. Discussion about biotechnology topics is not common in class. Many educators lack the abilities and expertise required to facilitate class discussions on biotechnology-related topics, particularly those pertaining to the social, political, ethical, and economic facets of the topics under debate (Indriyani, 2019). The quantity of subjects in the science curriculum feels restrictive to other educators (Reiss & Straughan, 1997) is also true that many scientific teachers avoid talking about the social, moral, and ethical ramifications of science and technology in the classroom because they see their job as factual instruction (Tal et al., 2019).

One of the most crucial elements in personal decision-making is the level of public interest in biotechnology products. Technology and risk can play a significant role in science literacy and education (Casanoves et al., 2015) argue that, for example, learning biotechnology is not just about content, but also about giving students the opportunity to learn based on understanding the strengths and weaknesses of modern biotechnology and forming their own opinions (Gardner & Jones, 2011).

CONCLUSION

Students' perspectives on biotechnology and their ability to argue can be improved by employing electronic modules that are based on socio-scientific issue topics. Argumentation skills between students from the experimental class or the class that uses socio-scientific issue-based electronic module learning and students from the control class or the class that uses electronic module learning show a significant average difference in improving argumentation skills. However, pupils' ability to argue is not improved by using electronic courses centred on socio-scientific issue topics. Meanwhile, the use of electronic modules that are not based on socio - scientific issues is very ineffective in improving students' argumentation skills.

There was a notable average difference in the way pupils in the experimental class and those in the control class saw biotechnology. There is a difference in the effectiveness of using socio-scientific issue-based electronic modules compared to regular electronic modules, but the N-Gain score criteria for using these modules to improve students' perceptions of biotechnology fall into the low category (N-gain = 0.21). Therefore, enhancing students' understanding of biotechnology by the use of socio-scientific issue-based electronic modules is ineffective. In the meantime, students' impressions of biotechnology are not improved by the employment of electronic modules that are not grounded in socio-scientific issue issues.

The comparatively low N-gain, however, points to a number of drawbacks, such as the intervention's brief duration, students' unfamiliarity with SSI-based learning, and limited interaction because the majority of the discussions took place online. Additionally, the learning exercises tended to focus more on cognitive than affective aspects. In order to gain a more thorough understanding of the effects of SSI-based learning, it is advised that future research implement SSI-based e-modules over a longer period of time, incorporate blended or in-person learning environments, and investigate affective, ethical, and attitudinal outcomes.

REFERENCES

Amalia, F., & Kustijono, R. (2017). Efektifitas Penggunaan E-Book dengan Sigil untuk Melatihkan Kemampuan Berpikir Kritis. *Prosiding Seminar Nasional Fisika (SNF)*, *1*(November), 81–85.

Banjer, H., Shami, A., Horaib, R. Bin, Almutiri, S., Alnemari, A., & Althumali, R. (2021). Biotechnology: knowledge, perception and future in Saudi Arabia. *Biotechnology and Biotechnological Equipment*, *35*(1), 1200–1206. https://doi.org/10.1080/13102818.2021.1955007

Bathgate, M., Crowell, A., Schunn, C., Cannady, M., & Dorph, R. (2015). The Learning Benefits of Being Willing and Able to Engage in Scientific Argumentation. *International Journal of Science Education*, *37*(10), 1590–1612. https://doi.org/10.1080/09500693.2015.1045958

Bögeholz, S., Eggert, S., Ziese, C., & Hasselhorn, M. (2017). *Modeling and Fostering Decision-Making Competencies Regarding Challenging Issues of Sustainable Development*. https://doi.org/10.1007/978-3-319-50030-0_16

Casanoves, M., González, Á., Salvadó, Z., Haro, J., & Novo, M. (2015). Knowledge and Attitudes Towards Biotechnology of Elementary Education Preservice Teachers: The first Spanish experience. *International Journal of Science Education*, *37*(17), 2923–2941. https://doi.org/10.1080/09500693.2015.1116718

Chen, S. Y., Chu, Y. R., Lin, C. Y., & Chiang, T. Y. (2016). Students' knowledge of, and attitudes towards biotechnology revisited, 1995-2014: Changes in agriculture biotechnology but not in medical biotechnology. *Biochemistry and Molecular Biology Education : A Bimonthly Publication of the International Union of Biochemistry and Molecular Biology*, *44*(5), 475–491. https://doi.org/10.1002/bmb.20969

Chowdhury, T., Holbrook, J., & Rannikmäe, M. (2020). Socioscientific Issues within Science Education and their Role in Promoting the Desired Citizenry. *Science Education International*, *31*(2), 203–208. https://doi.org/10.33828/sei.v31.i2.10

Christenson, N., Gericke, N., & Rundgren, S. N. C. (2017). Science and Language Teachers' Assessment of Upper Secondary Students' Socioscientific Argumentation. *International Journal of Science and Mathematics Education*, *15*(8), 1403–1422. https://doi.org/10.1007/s10763-016-9746-6

Chu, S. K. W., Reynolds, R. B., Tavares, N. J., Notari, M., & Lee, C. W. Y. (2017). 21st Century Skills Development Through Inquiry-Based Learning. In *21st Century Skills Development Through Inquiry-Based Learning: From Theory to Practice* (Issue August 2018).

Črne-Hladnik, H., Hladnik, A., Javornik, B., Košmelj, K., & Peklaj, C. (2012). Is Judgement of Biotechnological Ethical Aspects Related to High School Students' Knowledge? *International Journal of Science Education*, *34*(8), 1277–1296. https://doi.org/10.1080/09500693.2011.572264

Dawson, V., & Venville, G. (2013). Introducing High School Biology Students to Argumentation About Socioscientific Issues. *Canadian Journal of Science, Mathematics and Technology Education*, *13*(4), 356–372. https://doi.org/10.1080/14926156.2013.845322

Dawson, V., & Venville, G. J. (2009). High-school students' informal reasoning and argumentation about biotechnology: An indicator of scientific literacy? *International Journal of Science Education*, *31*(11), 1421–1445. https://doi.org/10.1080/09500690801992870

Eggert, S., Nitsch, A., Boone, W. J., Nückles, M., & Bögeholz, S. (2017). Supporting Students' Learning and Socioscientific Reasoning About Climate Change—the Effect of Computer-Based Concept Mapping Scaffolds. *Research in Science Education*, *47*(1), 137–159. https://doi.org/10.1007/s11165-015-9493-7

Fonseca, M. J., Costa, P., Lencastre, L., & Tavares, F. (2012a). Multidimensional analysis of highschool students' perceptions about biotechnology. *Journal of Biological Education*, *46*(3), 129–139. https://doi.org/10.1080/00219266.2011.634019

Fonseca, M. J., Costa, P., Lencastre, L., & Tavares, F. (2012b). Multidimensional analysis of highschool students' perceptions about biotechnology. *Journal of Biological Education*, *46*(3), 129–139. https://doi.org/10.1080/00219266.2011.634019

Gardner, G. E., & Jones, M. G. (2011). Science Instructors' Perceptions of the Risks of Biotechnology: Implications for Science Education. *Research in Science Education*, *41*(5), 711–738. https://doi.org/10.1007/s11165-010-9187-0

Gardner, G., & Jones, G. (2011). Perceptions and practices: Biology graduate teaching assistants' framing of a controversial socioscientific issue. *International Journal of Science Education*, *33*(8), 1031–1054. https://doi.org/10.1080/09500691003743244

Glassner, A., & Schwarz, B. B. (2007). What stands and develops between creative and critical thinking?. Argumentation? *Thinking Skills and Creativity*, *2*(1), 10–18. https://doi.org/10.1016/j.tsc.2006.10.001

Hancock, T. S., Friedrichsen, P. J., Kinslow, A. T., & Sadler, T. D. (2019). Selecting Socio-scientific Issues for Teaching. *Science & Education*, *28*(6–7), 639–667. https://doi.org/10.1007/s11191-019-00065-x

Hanegan, N. L., & Bigler, A. (2009). Infusing authentic inquiry into biotechnology. *Journal of Science Education and Technology*, *18*(5), 393–401. https://doi.org/10.1007/s10956-009-9155-5

Hani, E. S., & Mustapit. (2020). Undergraduate Students Attitudes toward Biotechnology Crop. *E3S Web of Conferences*, *142*, 1–4. https://doi.org/10.1051/e3sconf/202014206004

Indriyani, L. (2019). Pemanfaatan Media Pembelajaran Dalam Proses Belajar Untuk Meningkatkan Kemampuan Berpikir Kognitif Siswa. *Prosiding Seminar Nasional Pendidikan FKIP Universitas Sultan Ageng Tirtayasa*, *2*(1), 17–26.

Iordanou, K., & Constantinou, C. P. (2015). Supporting use of evidence in argumentation through practice in argumentation and reflection in the context of SOCRATES learning environment. *Science Education*, *99*(2), 282–311. https://doi.org/10.1002/sce.21152

Irwan, I., Maridi, M., & Dwiastuti, S. (2019). Developing guided inquiry-based ecosystem module to improve students' critical thinking skills. *Jurnal Pendidikan Biologi Indonesia*, *5*(1), 51–60. https://doi.org/10.22219/jpbi.v5i1.7287

Jayanti, F., & Arista, N. T. (2019). Persepsi Mahasiswa Terhadap Pelayanan Perpustakaan Universitas Trunojoyo Madura. *Competence : Journal of Management Studies*, *12*(2), 205–223. https://doi.org/10.21107/kompetensi.v12i2.4958

Jho, H., Yoon, H. G., & Kim, M. (2014). The Relationship of Science Knowledge, Attitude and Decision Making on Socio-scientific Issues: The Case Study of Students' Debates on a Nuclear Power Plant in Korea. *Science and Education*, *23*(5), 1131–1151. https://doi.org/10.1007/s11191-013-9652-z

Kaya, E., Erduran, S., & Cetin, P. S. (2010). High school students' perceptions of argumentation. *Procedia - Social and Behavioral Sciences*, *2*(2), 3971–3975. https://doi.org/10.1016/j.sbspro.2010.03.625

Kemdikbud. (2020). Panduan Penyelenggaraan Pembelajaran di Masa Pandemi COVID-19. *Kemendikbud*, *2019*, 1–58. https://www.kemdikbud.go.id/main/blog/2020/06/buku-saku-panduan-pembelajaran-di-masa-pandemi-covid19

Khishfe, R. (2012). Nature of Science and Decision-Making. *International Journal of Science Education*, *34*(1), 67–100.

https://doi.org/10.1080/09500693.2011.559490

Klop, T., & Severiens, S. (2007). An exploration of attitudes towards modern biotechnology: A study among Dutch secondary school students. *International Journal of Science Education*, *29*(5), 663–679. https://doi.org/10.1080/09500690600951556

Kolarova, T. (2011). Modern Biotechnology from The Point of View of 15–19-Year-Old High School Students. *Biotechnology & Biotechnological Equipment*, *25*(3), 2538–2546. https://doi.org/10.5504/BBEQ.2011.0069

Larasati, A. A. (2019). Pengembangan Media Pembelajaran … Pengembangan Media Pembelajaran …. *AL-Ahya*, *01*(01), 219–232.

Lindahl, M. G., & Lundin, M. (2016). How do 15–16 year old students use scientific knowledge to justify their reasoning about human sexuality and relationships? *Teaching and Teacher Education*, *60*, 121–130. https://doi.org/10.1016/j.tate.2016.08.009

Mohapatra, A. K., Priyadarshini, D., & Biswas, A. (2010). Genetically Modified Food: Knowledge and Attitude of Teachers and Students. *Journal of Science Education and Technology*, *19*(5), 489–497. https://doi.org/10.1007/s10956-010-9215-x

Moreno-Guerrero, A. J., Romero-Rodríguez, J. M., López-Belmonte, J., & Alonso-García, S. (2020). Flipped learning approach as educational innovation in water literacy. *Water (Switzerland)*, *12*(2). https://doi.org/10.3390/w12020574

Norris, S. P., & Phillips, L. M. (2003). How Literacy in Its Fundamental Sense Is Central to Scientific Literacy. *Science Education*, *87*(2), 224–240. https://doi.org/10.1002/sce.10066

Nuraini, A., & Ronoatmodjo, S. (2018). The Effectiveness of Comic as Learning Media to Enhance Knowledge of Menarche and Menstruation among Female Students in Yogyakarta. *Journal of Health Promotion and Behavior*, *3*(4), 257–262. https://doi.org/10.26911/thejhpb.2018.03.04.05

Permana, T. I., Suwono, H., & Listyorini, D. (2016). Analisis Persepsi Dosen terhadap Strategi Pembelajaran Reading, Questioning, and Answering (RQA) dan Argument-Driven Inquiry (ADI) pada Program Studi Pendidikan Biologi di Kota Makassar. *Prosiding Seminar Nasional II 2016, Kerjasama Prodi Pendidikan Biologi FKIP Dengan Pusat Studi Lingkungan Dan Kependudukan (PSLK) Universitas Muhammadiya Malang*, *3*(1), 1019–1028.

Pratiwi, Y. N., Rahayu, S., & Fajaroh, F. (2016). Socioscientific issues (SSI) in reaction rates topic and its effect on the critical thinking skills of high school students. *Jurnal Pendidikan IPA Indonesia*, *5*(2), 164–170. https://doi.org/10.15294/jpii.v5i2.7676

Purwati, R., Suranto, Sajidan, & Prasetyanti, N. M. (2019). Problem-Based Learning Modules with Socio-Scientific Issues Topics to Closing the Gap in Argumentation Skills. *TOJET: The Turkish Online Journal of Educational Technology*, *18*(4), 35–45.

Reis, P. (2004). The impact of socio-scientific controversies in Portuguese natural science teachers' conceptions and practices. *Research in Science Education*, *34*(2), 153–171. https://doi.org/10.1023/B:RISE.0000033760.04656.a1

Reiss, M., & Straughan, R. (1997). IMPROVING NATURE ?: THE SCIENCE AND ETHICS OF GENETIC ENGINEERING Harvard Journal of Law & Technology agencies have stated that genetic engineering is essentially an amplifica- tion of more traditional forms of biotechnology , such as breeding , 5 the aut. *Harvard Journal of Low and Technology*, *10*(3), 288.

Sadler, T. D. (2004). Moral sensitivity and its contribution to the resolution of socio-scientific issues. *Journal of Moral Education*, *33*(3), 339–358. https://doi.org/10.1080/0305724042000733091

Sadler, T. D., & Zeidler, D. L. (2005). Patterns of informal reasoning in the context of socioscientific decision making. *Journal of Research in Science Teaching*, *42*(1), 112–138. https://doi.org/10.1002/tea.20042

Sáez, M. J., Niño, A. G., & Carretero, A. (2008). Matching society values: Students' views of biotechnology. *International Journal of Science Education*, *30*(2), 167–183. https://doi.org/10.1080/09500690601152386

Saifuddin, F., Putro, S. C., & Irianto, W. S. G. (2020). Pengembangan modul pembelajaran interktif pemrograman dasar bermuatan model pembelajaran problem based learning untuk memahamkan konsep pemrograman siswa kelas X program keahlian TKJ di SMK Cendika Bangsa Kepanjen. *Jurnal Teknologi, Kejuruan, Dan Pengajarannya*, *43*(1), 51–61. http://journal2.um.ac.id/index.php/teknologi-kejuruan/article/view/16644

Tal, T., Levin-Peled, R., & Levy, K. S. (2019). Teacher views on inquiry-based learning: the contribution of diverse experiences in the outdoor environment. *Innovation and Education*, *1*(1), 1–17. https://doi.org/10.1186/s42862-019-0004-y

Tekin, N., Aslan, O., & Yılmaz, S. (2020). Improving Pre-Service Science Teachers' Content Knowledge and Argumentation Quality through Socio-Scientific Issues-Based Modules: An Action Research Study. *Journal of Science Learning*, *4*(1), 80–90. https://doi.org/10.17509/jsl.v4i1.23378

Wahidah, N. S., Supriatno, B., & Kusumastuti, M. N. (2018). Analisis Struktur dan Kemunculan Tingkat Kognitif pada Desain Kegiatan Laboratorium Materi Fotosintesis. *Assimilation: Indonesian Journal of Biology Education*, *1*(2), 70–76. https://doi.org/10.17509/aijbe.v1i2.13050

Walgito, B. (2015). Pengantar Psikologi Umum. Yogyakarta. In *Paper Knowledge . Toward a Media History of Documents*.

Wüstenberg, S., Stadler, M., Hautamäki, J., & Greiff, S. (2014). The role of strategy knowledge for the application of strategies in complex problem solving tasks. *Technology, Knowledge and Learning*, *19*(1–2), 127–146. https://doi.org/10.1007/s10758-014-9222-8

Yapıcıoğlu, A. E. (2018). Advantages and Disadvantages of Socioscientific. *International Online Journal of Education and Teaching (IOJET)*, *5*(2), 361–374.

Zamakhsyari, & Rahayu, S. (2020). Fostering ill-structured problem-solving skills of chemistry students using socioscientific issues as learning contexts. *AIP Conference Proceedings*, *2215*(April). https://doi.org/10.1063/5.0000533