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SOCIOSCIENTIFIC ISSUES AS A PEDAGOGICAL APPROACH TO FOSTER SCIENTIFIC ARGUMENTATION IN BIOPLASTIC PRODUCTION USING SUGARCANE BAGASSE

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ABSTRACT

This study aims to develop students' scientific argumentation through the implementation of socioscientific issues-based learning in the context of bioplastic production from sugarcane bagasse (*Saccharum officinarum*). A pre-experimental method employing a one-shot case study design was conducted involving 36 eleventh-grade Industrial Chemistry students at a vocational high school (SMK) in Cimahi City. Four research instruments were utilized: (1) student worksheets designed to facilitate contextual problem analysis, laboratory experimentation, and reflective thinking; (2) argumentation debates addressing environmental and scientific issues surrounding plastic waste and bioplastics; and (3) scientific argumentation tests structured according to the Toulmin Argumentation Pattern, assessing students' ability to construct claims, support them with evidence, provide reasoning, and offer rebuttals. Student outputs included Students' work includes experimental reports, scientific argumentation tests, and oral debates. Data were analyzed using rubric-based scoring and converted to percentage values. The findings indicate a high level of student performance in completing worksheets (average score: 91), categorized as "very good." Oral argumentation predominantly reached level 2 (claim with evidence), while written argumentation reached level 3 (arguments including weak rebuttals). These results suggest that socioscientific issues-based learning is effective in fostering students' scientific argumentation skills, though further scaffolding is required to strengthen rebuttal quality.

Keywords: socioscientific issues, scientific argumentation, bioplastic, sugarcane bagasse

INTRODUCTION

Skills that can help individuals achieve success in life are highly essential in the era of the Fourth Industrial Revolution. Education in the 21st century places strong emphasis on several key areas, such as communication, critical thinking and problem-solving, teamwork, creativity, as well as skills and understanding (Prayogi, 2020). Argumentation can facilitate the development of several 21st-century competencies, including critical thinking, problem-solving, and communication skills (López-Fernández et al., 2022). Problem-solving skills are a crucial aspect of chemistry education (Sunarya et al., 2024). Science learning that incorporates an argumentation-based approach can be implemented by presenting a specific problem topic (Ross et al., 2019). Students are required to construct statements and explanations by adding supporting data based on their foundational scientific knowledge and existing theories (Sunarya et al., 2023).

Socioscientific issues-based learning is one strategy that can be used to enhance students' knowledge and abilities. This approach not only teaches scientific topics but also connects them to relevant social issues (Owens et al., 2019). Each stage of the scientific approach can reveal observable characteristics during the learning process (Subarkah et al., 2016). Students' ability to formulate claims, provide evidence, and construct arguments based on scientific data serves as an indicator of the success of this learning approach. Socioscientific issues are social problems with no clear-cut solutions and are closely related to natural science (Wilsa et al., 2017).

Argumentation is a process that attempts to support claims with reasons. Claim, evidence, reasoning, and rebuttal are the four components of the Toulmin Argument Pattern (TAP), which consists of several indicators of scientific argumentation ability (Acar & Patton, 2012). A *claim* is a statement or judgment made during the course of an argument. Scientific data that support the claim, as well as the collection and integration of such data to reinforce the statement, are referred to as *evidence*. *Reasoning* is the process of linking the claim to the supporting data. A *rebuttal* is a counter-claim that contradicts the data, along with an explanation of the relationship between the claim and the facts (Stanford et al., 2016).

Students' argumentation skills remain relatively low, which affects both the learning process and learning outcomes (Rahayu et al., 2020). Students experience difficulties in presenting arguments to explain the results of scientific work (Sunarya et al., 2022). Moreover, students rarely practice their argumentation skills during problem-solving learning processes related to socioscientific issues. Previous studies have demonstrated the effectiveness of socioscientific issues-based learning in enhancing students' argumentation skills, particularly in science education, by providing real-world contexts that stimulate critical thinking and meaningful discussions. Socioscientific issues-based learning is one of the strategies that can be used to address this issue. This approach integrates scientific contexts with relevant social issues to help students understand the implications of scientific judgment (Istiana et al., 2019; Sadler et al., 2016). However, limited research has applied this pedagogical approach specifically within chemistry learning environments, indicating a need for further investigation in this area.

One of the current emerging social issues is plastic waste. Plastic waste, which is made from synthetic polymers derived from petroleum, takes a long time to decompose. The increasing use of plastic packaging has also posed significant challenges in waste management (Nairfana & Ramdhani, 2021). In an effort to reduce the accumulation of plastic waste, research has been conducted to develop environmentally friendly plastics, namely bioplastics or biodegradable plastics.

Bioplastic is a type of plastic that is biodegradable—an environmentally friendly plastic that can be naturally decomposed by bacteria, fungi, and algae, eventually breaking down into carbon dioxide and water through the action of microorganisms. Starch is the primary raw material used in most studies on the production of biodegradable polymers. However, the use of starch as a raw material may also raise new concerns, as it is a food source for humans, thereby increasing the risk of a food crisis (Dawam Abdullah et al., 2021).

Sugarcane bagasse contains a high amount of cellulose; however, its utilization has not been optimal. Sugarcane bagasse consists of 45.96% cellulose, 20.37% hemicellulose, and 21.56% lignin. Materials with a cellulose content of 40% can be used as a raw material for bioplastic sheet production. Plant polysaccharides, including cellulose, starch, and protein, can be utilized to produce plastics. The advantage of using cellulose in biodegradable plastics is its high tensile strength, which can enhance the mechanical quality of biodegradable plastics (Kalsum et al., 2020). The utilization of sugarcane bagasse waste as a raw material for bioplastic is not only socially relevant but also aligns with the principles of green chemistry, There are 12 principles of green chemistry designed to minimize the negative impacts on the environment and human health through more sustainable chemical approaches (Whiteker, 2019). In the context of this study, the application of these principles is reflected in Principle 1 (Prevention), by utilizing waste to reduce the generation of new waste; Principle 7 (Use of renewable feedstocks), through the use of lignocellulosic agricultural residues; and Principle 10 (Design for degradation), by producing materials that are biodegradable and environmentally friendly.

This study contributes to several Sustainable Development Goals (SDGs), particularly under the Planet and People pillars. By promoting environmentally friendly bioplastics from agricultural waste, the research supports SDG 12 (Responsible Consumption and Production) and SDG 13 (Climate Action) (Diouf, 2019). SDG 12 is addressed through the reduction of plastic waste and the efficient use of renewable agricultural by-products, minimizing reliance on fossil-based plastics and decreasing environmental pollution. Meanwhile, SDG 13 is supported by lowering greenhouse gas emissions associated with conventional plastic production and disposal, thus mitigating climate change impact. Simultaneously, by enhancing students' scientific literacy and critical thinking through socioscientific issues-based learning, it aligns with SDG 4 (Quality Education).

The aim of this study is to develop students' scientific argumentation skills through the implementation of socioscientific issues-based learning in the context of bioplastic production from sugarcane bagasse (*Saccharum officinarum*). Although previous studies have demonstrated the effectiveness of socioscientific issues in enhancing argumentation skills in science education (Istiana et al., 2019; Sadler et al., 2016), limited research has applied this pedagogical approach specifically in chemistry learning using real-world issues derived from local agricultural waste. The novelty of this study lies in the integration of relevant environmental and social issues—namely plastic pollution and the potential of bioplastics made from sugarcane waste—into the learning process to develop students' scientific argumentation. This approach not only contextualizes chemistry content, but also promotes critical thinking and awareness of sustainability issues (Mammino, 2019).

RESEARCH METHOD

The method used was a pre-experimental design with a one-shot case study, involving one experimental class and no control group. Only one treatment was applied in this research design, which was assumed to have an effect. This treatment involved implementing Socioscientific Issues-based worksheets, followed by observation and inference (Sugiyono, 2017). The research activities were divided into three stages: the initial stage, the implementation stage, and the final stage. The initial stage included a preliminary study and a literature review related to socioscientific issues and scientific argumentation. In the implementation stage, instruments developed and validated by three experts were used. At the final stage, scientific argumentation levels were analyzed and interpreted based on data from student worksheets and scientific argumentation tests. A flowchart illustrating the research procedures—including each stage, the activities performed, and the outputs produced—is provided in Figure 1.

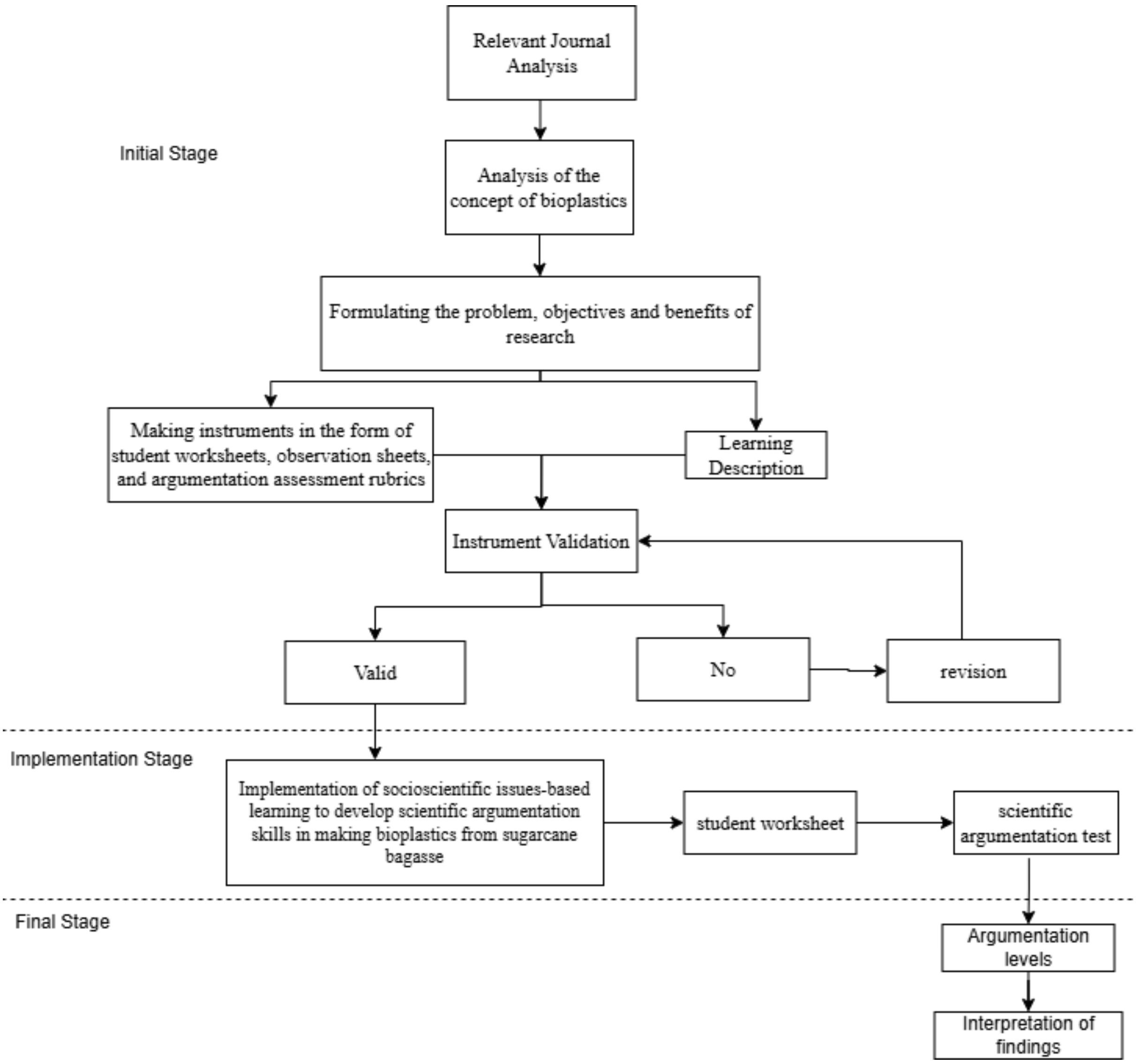


Figure 1. Research Procedures

Instrument validation results was calculated as a percentage score distribution to ensure the suitability level of the instruments in terms of language, construction, and content, using the formula:

$$Percentage = \frac{Obtained\ skor}{Maximum\ score}\ x\ 100\%$$

The percentage results of the instrument feasibility can be categorized based on Table 1.

Table 1. Criteria for Expert Validation Percentage Analysis *(Arikunto, 2013)*

Percentage of Feasibility (%)	Category
75-100	Highly feasible
50-75	Feasible
25-50	Not feasible
0-25	Highly not feasible

The feasibility percentage values of the research instruments from three expert validators are shown in Table 2.

Table 2. Instrument Validation Results

Validated Aspects	Validator I	Validator II	Validator III	Aspect Average
Content construction	92%	92%	100%	94.7%
Presentation technique	92%	92%	75%	86.3%
Completeness of presentation	100%	96%	83%	93%
Language readability	100%	75%	81%	85.3%
Validator Average	96%	88.8%	84.8%	89.9%
Interpretation	Highly feasible	Highly feasible	Highly feasible	Highly feasible

The socioscientific issues learning steps included problem analysis, problem clarification, continuation of the social issue, discussion and evaluation, as well as metareflection (Rostikawati & Permanasari, 2016). This study focused on students' learning outcomes, as well as the development of argumentation gained through the implementation of socioscientific issues-based learning in the production of bioplastics from sugarcane bagasse. The research participants were 36 students from Class XI B Industrial Chemistry at a Vocational High School (SMK) in Cimahi City, selected because the topic of green chemistry was scheduled to be taught in their curriculum, and had access to appropriate laboratory facilities to support bioplastic production activities.

The data collection techniques in this study included student worksheets and scientific argumentation tests. The instruments used comprised student worksheets, argumentation debates, and scientific argumentation tests. Data were analyzed using rubrics tailored to each instrument. Argumentation quality was measured using the Toulmin framework (Level 0–5), while student worksheet completion was scored and interpreted as percentage-based categories.

Data regarding the development of students' scientific argumentation skills during the learning process were collected through the use of student worksheets under the topic of bioplastic production from sugarcane bagasse, applying the Socioscientific Issues (SSI)-based learning model. Assessment was conducted, and the results were converted into numerical scores using the following formula:

$$Score = \frac{Total\ score\ obtained}{Maximum\ score}\ x\ 100$$

The average test score was calculated using the following formula:

$$Average = \frac{Total\ score\ from\ all\ students}{Number\ of\ students}$$

Once the scores were obtained, they were interpreted using the scale for assessing students' capabilities as presented in Table 3.

Table 3. Assessment Criteria for Student Worksheets *(Sugiyono, 2017)*

Skor Range	Description
80-100	Very Good
70-79	Good
60-69	Fair
50-59	Poor
0-49	Very Poor

During student participation in debate sessions, the affective component of this format is evaluated. This includes the ability to accurately communicate ideas in group discussions, respond appropriately and precisely to questions or rebuttals, and respect others' perspectives (Walker et al., 2019). These three main components of scientific argumentation skills are included in the assessment.

The scientific argumentation test items used have undergone validity testing using Anates software. The analysis results showed a correlation value between item scores and total scores of 0.8, which is categorized as very strong. Therefore, the test items were declared valid and suitable for use in the study. The test was administered at the end of the learning process and subsequently analyzed. The levels for each indicator in students' answers were determined using the provided evaluation rubric. To assign scores for each argumentation component in assessing the argumentation, the analytical framework for the quality of students' written argumentation developed by Toulmin's Argument Pattern (TAP) was employed (Erduran et al., 2022). The quality indicators for argumentation levels are presented in Table 4.

Table 4. Quality Indicators of Argumentation Levels *(Acar & Patton, 2012)*

Level	Criteria
0	Argumentation consists of only a claim
1	Argumentation includes a basic (simple) claim debated against another claim within an argument.
2	Argumentation includes a claim supported by evidence or data and explanation (reasoning) but does not include a rebuttal
3	Argumentation consists of a weak rebuttal and a claim against another claim supported by supporting evidence and explanation (reasoning)
4	Argumentation includes multiple optional statements supported by evidence or facts as well as an argument with one clear rebuttal
5	Argumentation presents an extended claim with several convincing counterarguments (rebuttals)

RESULT AND DISCUSSION

The implementation of socioscientific issues-based learning in the development of bioplastics from sugarcane bagasse was conducted over two meetings with Grade XI B students majoring in Industrial Chemistry at a vocational high school (SMK) in Cimahi City. The first meeting focused on the process of converting sugarcane bagasse into bioplastic through experimentation and the completion of student worksheets. In the second meeting, students presented the results of their experiments. The presentation materials were delivered in the form of posters. Socioscientific issues-based learning utilizes real-world issues with social impacts, such as environmental problems caused by conventional plastic use. Through the topic of bioplastic production as an environmentally friendly alternative, students were encouraged to construct evidence-based scientific arguments in response to the issue.

Student Worksheet

The worksheet was organized into five phases aligned with the stages of socioscientific issues-based learning: problem approach and analysis, problem clarification, extending the socioscientific issue, discussion and evaluation, and metareflection. The presentation of the scores for students' performance in completing the worksheet during socioscientific issues-based learning is shown in Table 6.

Table 5. Scores of Student Worksheet Completion Ability

No	Learning Phases	Average	Category
1	Problem Approach and Analysis	100	Very Good
2	Problem Clarification	85	Very Good
3	Extending the Socioscientific Issue	89	Very Good
4	Discussion and Evaluation	84	Very Good
5	Metareflection	96	Very Good
Completion of Worksheet (%)		91	Very Good

Based on the results presented in Table 5, The analysis results indicate that the average completion rate of the worksheets was 91%, with a standard deviation of 12.61. This suggests that students' overall performance was high, although there was some variation among students and across different phases of the learning process. The average score for each learning phase was calculated using the average score of students in each phase. The standard deviation was calculated using the built-in function in Microsoft Excel to show the variability of the data in each phase. In the phase of problem approach and analysis, students were given an initial stimulus in the form of questions that encouraged them to express opinions or claims related to environmental issues and the use of conventional plastics derived from petroleum. Providing initial stimulus in the form of real questions or issues encourages students to identify problems and develop complex arguments (Wati et al., 2023). This activity elicited argumentation at the initial level, namely the ability to formulate claims relevant to the problem context. Students began to recognize the existence of real issues that require scientific solutions. They were trained not only to state opinions but also to formulate claims that can be scientifically justified (Grooms, 2020). Cognitively, this activity activated critical thinking skills and directed students to focus on the main issue. The average student activity implementation score in this first phase was 100, categorized as very good. An example of a question and student response from Phase 1 can be seen in Figure 2.

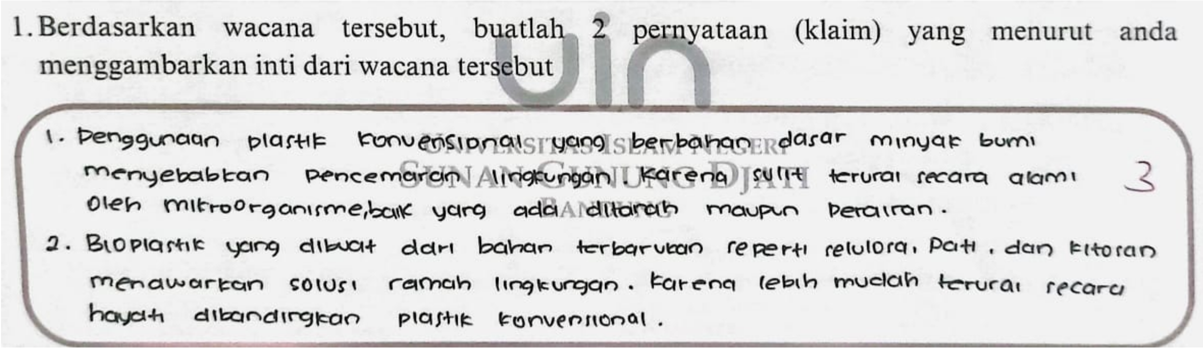


Figure 2. Example of Student Response During The Problem Approach and Analysis Phase

In the second phase, namely problem clarification, students were required to explore and document scientific evidence based on the experiments conducted. Through activities such as creating experimental procedure flowcharts and recording observation results, students developed the scientific argumentation aspect in the evidence component. Argumentation is crucial because it encourages students not only to make speculative claims but to construct arguments based on experimental data (Hosbein et al., 2021). An example of a flowchart created by students is shown in Figure 3.

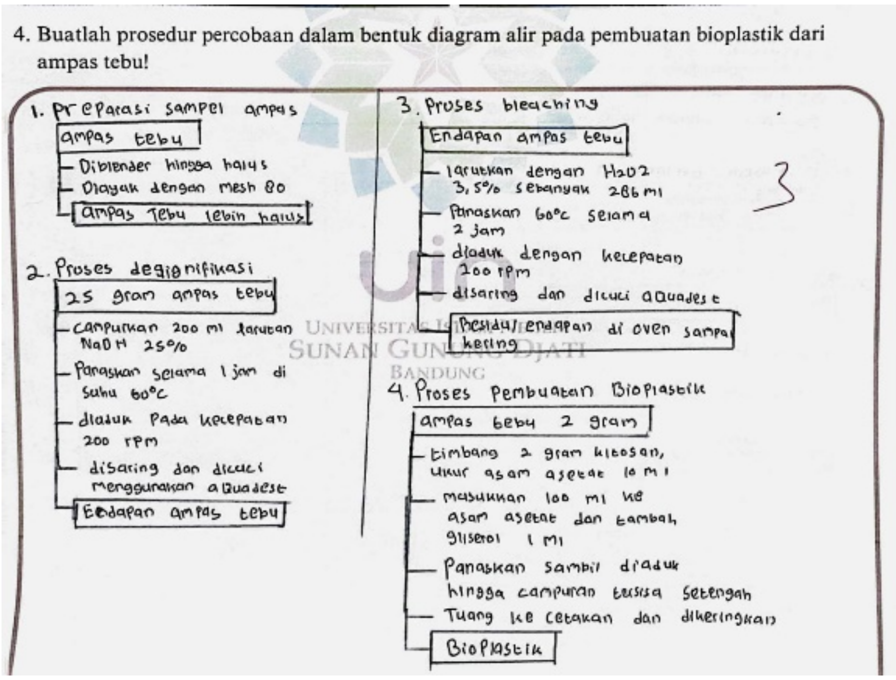


Figure 3. Example of Experimental Procedure Flowchart

Thus, the clarification process strengthens students' scientific literacy through documentation, observation, and validation of evidence within the structure of scientific argumentation. The average student activity implementation score in this second phase was 85, categorized as very good. During this phase, students also produced bioplastic products from the bagasse they had made. Images of the bioplastic products can be seen in Figure 4.

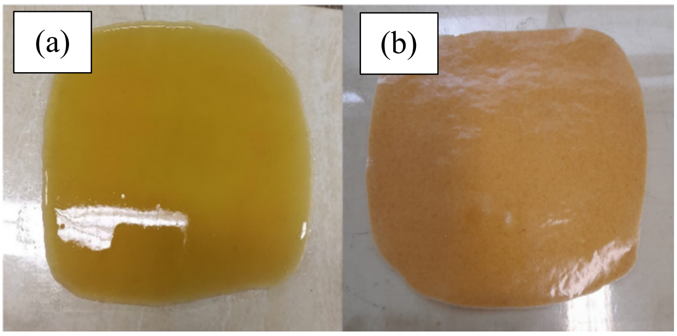
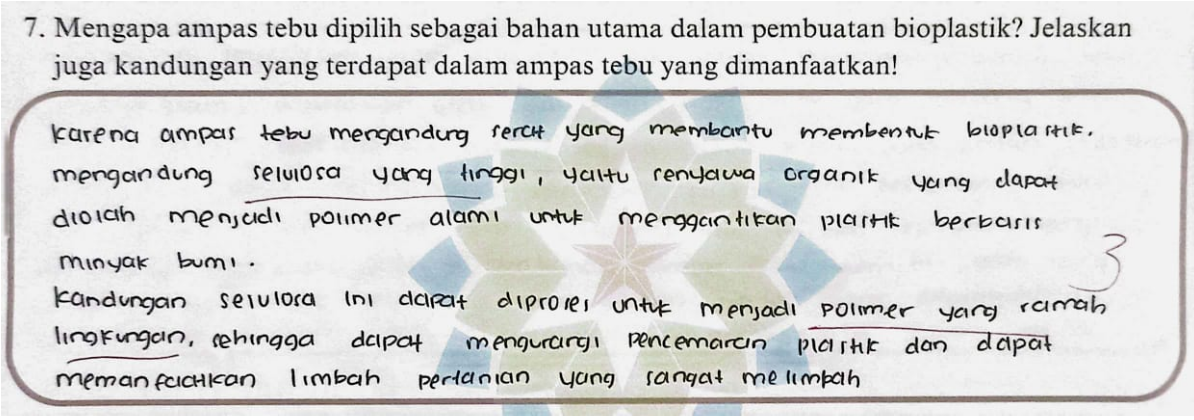


Figure 4. The Bioplastic Products Using Sugarcane Bagassed From The Learning Process Are (a) Wet; and (b) Dry

In the third phase, students were provided with extended discourse regarding the abundance of sugarcane bagasse and its potential as a raw material for bioplastics. Students were then asked to develop further claims and construct support based on scientific information, such as the cellulose content in sugarcane bagasse. This process challenged students to integrate scientific information with social and environmental contexts, enabling them to build arguments that are not only conceptually accurate but also socially relevant (Nida et al., 2021). The average implementation score of student activities in this third phase was 89, categorized as very good. The bioplastic produced in this study is a composite of chitosan, glycerol, acetic acid, and water, with the addition of sugarcane bagasse as a natural reinforcing filler. The purification process of sugarcane bagasse to obtain pure cellulose involves delignification using NaOH to remove lignin, followed by bleaching with H_2O_2 to reduce hemicellulose and other impurities (Ritonga et al., 2023). The presence of cellulose from sugarcane bagasse contributes to strengthening the bioplastic structure, enhancing homogeneity, and improving mechanical stability. The variation in the amount of bagasse added serves as a key differentiator in the products, as it contributes to the biodegradability of the bioplastic. An example of a question and student response from Phase 3 can be seen in Figure 5.

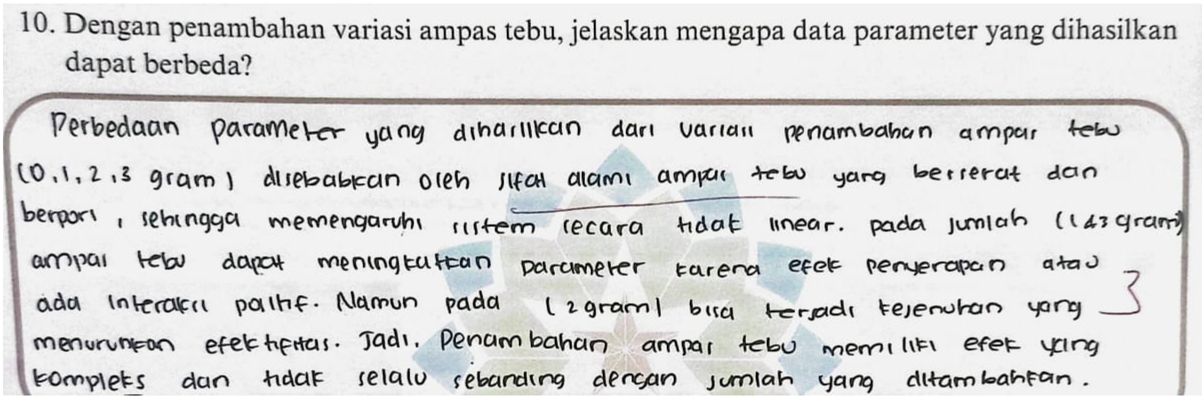

7. Mengapa ampas tebu dipilih sebagai bahan utama dalam pembuatan bioplastik? Jelaskan juga kandungan yang terdapat dalam ampas tebu yang dimanfaatkan!

karena ampas tebu mengandung serat yang membantu membentuk bioplastik. mengandung selulosa yang tinggi, yaitu senyawa organik yang dapat diolah menjadi polimer alami untuk menggantikan plastik berbasis minyak bumi.
Kandungan selulosa ini dapat diproses untuk menjadi polimer yang ramah lingkungan, sehingga dapat mengurangi pencemaran plastik dan dapat memanfaatkan limbah pertanian yang sangat melimpah

3

Figure 5. An Example of A Students Response in Phase of Extending The Socioscientific Issues

The fourth phase, discussion and evaluation, provides students the opportunity to test the strength of their arguments based on the variations of bioplastics produced. In this activity, students demonstrate their ability to present counter-claims, reasoning, and rebuttals, which are core elements of advanced scientific argumentation. The discussion encourages students not only to defend their own views but also to refute others' opinions with logical and data-based justifications. Well-facilitated discussions allow students to connect positions to relevant reasons and evidence (Wilkinson et al., 2023). This activity strengthens higher-order cognitive skills, including reflective, evaluative, and logical thinking in constructing and sustaining valid scientific arguments. The average level of student activity during the fourth phase received a score of 84, categorized as very good. An example of a question along with a student's response from the fourth phase can be seen in Figure 6.


10. Dengan penambahan variasi ampas tebu, jelaskan mengapa data parameter yang dihasilkan dapat berbeda?

Perbedaan parameter yang dihasilkan dari variasi penambahan ampas tebu (0,1,2,3 gram) disebabkan oleh sifat alami ampas tebu yang berserat dan berpori, sehingga memengaruhi sistem secara tidak linear. pada jumlah (1&3 gram) ampas tebu dapat meningkatkan parameter karena efek penyerapan atau ada interaksi positif. Namun pada (2 gram) bisa terjadi kejenuhan yang menurunkan efektifitas. Jadi, penambahan ampas tebu memiliki efek yang kompleks dan tidak selalu sebanding dengan jumlah yang ditambahkan.

3

Figure 6. Example of Student Response During the Discussion and Evaluation Phase

The final phase of this learning process is metareflection, during which students formulate conclusions from the entire series of activities and present their results in the form of a scientific poster. This activity encourages students to synthesize and evaluate the arguments they have constructed, while also communicating those arguments effectively. Presentations not only train students to organize their arguments systematically but also reinforce the metacognitive aspects of scientific argumentation. Meta-reflection is an advanced form of reflective practice that is carried out collaboratively by two or more individuals. In this process, individuals do not merely review their experiences or activities, but also critically analyze their own thinking and practices, allowing them to move from descriptive reflection to deeper, more analytical reflection (Thorpe & Garside, 2017). By encouraging students to engage in meta-reflection, they can develop critical thinking skills and enhance their ability to evaluate and construct stronger scientific arguments . Through this phase, students are expected to reflect on their thinking processes and recognize the importance of constructing data-based arguments in addressing socially nuanced scientific issues. While general reflection typically involves reviewing what was done and learned, metareflection refers to a deeper process where students critically examine how they think, how their arguments were constructed, and how their thinking evolved throughout the learning activities. The average level of student activity during the fifth phase received a score of 96, categorized as very good. An example of a poster created by the students can be seen in Figure 7.

Figure 7. Sample of Laboratory Report Presented as a Poster

Analysis of the Development of Scientific Argumentation

The development of scientific argumentation skills can be analyzed both orally and in writing. Oral analysis is conducted during the presentation session. The categorization of students' development in scientific argumentation skills is based on the argumentation quality levels referring to Toulmin's Argument Pattern as shown in Table 4.

Argumentation in science is important when considering claims derived from data analysis and how the data supports those claims (Bowen et al., 2018). An example of presenting a claim during the presentation is: "Sugarcane bagasse serves as the primary source of cellulose, which provides mechanical strength to the bioplastic while utilizing abundant biomass." The summary of students' scientific argumentation performance is presented in Table 6.

Table 6. Recapitulation of Students' Oral Scientific Argumentation

Argumentation Level	Group						Number of Student
	1	2	3	4	5	6	
Level 0	-	1	-	-	-	-	1
Level 1	-	-	-	-	-	-	-
Level 2	5	1	4	2	5	2	19
Level 3	1	3	-	3	1	1	9
Level 4	-	1	2	1	-	3	7
Level 5	-	-	-	-	-	-	-
Total							36

Based on the data in Table 6, it can be stated that the majority of students' oral argumentation is at level 2, which includes arguments consisting of claims supported by evidence or data and explanations, but does not include rebuttals.

The written analysis was conducted through the results of the scientific argumentation test, based on the levels achieved on the argumentation test items. The distribution of test argumentation levels is also presented in Table 7.

Table 7. Average Level Scores of Scientific Argumentation Test Items

Item Number	Indicator of Each Item	Average Argumentation Level (0-5)	Interpretation
1	Students are able to express opinions about what sugarcane bagasse is and the components that make it suitable as a raw material for bioplastics	2	Argument includes evidence but lacks rebuttal
2	Students are able to provide opinions related to soil and water quality as well as global balance affected by the processing of sugarcane bagasse	2	Argument includes evidence but lacks rebuttal

	waste into bioplastics as an alternative to conventional plastics		
3	Students can explain opinions supported by scientific reasons regarding the necessity of delignification and bleaching processes in the processing of sugarcane bagasse into bioplastics	2	Argument includes evidence but lacks rebuttal
4	Students are able to construct logical and structured scientific arguments regarding the effectiveness of raw materials in bioplastic production	3	Argument with weak rebuttal
5	Based on the presented table, students are able to construct precise and clear scientific arguments regarding differences in the parameters of the produced bioplastics	3	Argument with weak rebuttal
	Average	3	Argument with weak rebuttal

Overall, the average level of quality of students' written scientific arguments is at level 3. This indicates that the arguments consist of weak rebuttals and claims against other claims, supported by evidence and reasoning. Based on the analysis of five argumentation-based questions, students demonstrated an average argumentation level of 3 with a standard deviation of 0.94. This suggests that, on average, students were able to formulate scientific claims supported by appropriate reasoning and evidence. However, the standard deviation indicates a moderate level of variation among students' argumentation abilities. While several students performed at or near the average level, others exhibited either more advanced or more basic levels of argumentation. This variability may reflect differences in prior knowledge, engagement, or the effectiveness of the instructional intervention in accommodating diverse learners. The percentage distribution of students at each level of written argumentation quality can be seen in Table 8.

Table 8. Recapitulation of Students' Written Scientific Argumentation

Argumentation Level	Level Characteristics	Number of Students
0	Argumentation consists of claims only	-
1	Argumentation includes basic (simple) claims debated against other claims within an argument	2
2	Argumentation includes claims supported by evidence or data and explanations (reasoning) but lacks rebuttals	12
3	Argumentation consists of weak rebuttals and claims against other claims supported by evidence and explanation	22

4	Argumentation includes multiple optional statements supported by evidence or facts, as well as arguments with one clear rebuttal	-
5	Argumentation presents extended claims with several convincing counterarguments (rebuttals)	-
	Total	36

Based on the data presented in Table 8, the students' written argumentation levels obtained through the test were distributed across levels one, two, and three. The majority of students demonstrated argumentation quality at level three, with 22 students; the fewest were at level one, with only 2 students; and the remaining 12 students were at level two. Therefore, socioscientific issues-based learning in the context of bioplastic production from sugarcane bagasse (*Saccharum officinarum*) has the potential to develop students' scientific argumentation skills.

CONCLUSION

Students' ability to complete the worksheets achieved an average score of 98, which also falls into the very good category. These achievements indicate that students were not only physically active during learning but also able to comprehend and apply the material appropriately within the context of the assigned tasks. Based on observations of oral argumentation skills, most students reached level 2, which is characterized by the presentation of claims supported by evidence, although not yet accompanied by rebuttals to opposing claims. Meanwhile, the quality of written scientific argumentation reached level 3 following the implementation of socioscientific issues-based learning. This level is marked by the inclusion of rebuttals to other claims, although the rebuttals remain relatively weak. These findings indicate that socioscientific issues-based learning holds significant potential in developing students' scientific argumentation skills. However, further efforts and reinforcement strategies in instruction are necessary to encourage students to construct stronger, more relevant, and data-based rebuttals.

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