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The Application of Socioscientific Issues (SSI)-Based Learning to Develop Scientific Argumentation Skills in the Production of Bio-foam (Biodegradable Styrofoam) from Sugarcane Bagasse

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Abstract

SSI-based learning focuses on the complex problems that develop throughout society. SSI holds significant implications for society, requiring students, as the future generation, to actively participate in dialogue, discussion, debate, and argumentation. The purpose of this study is to analyse the development process of scientific argumentation skills in the production of bio-foam using sugarcane bagasse (Saccharum officinarum Linn). We have adopted a pre-experimental methodology, utilising a one-shot case study design. Students' observation sheets and SSI-based worksheets serve as research instruments, assessing their scientific analytical skills. The research findings reveal that students' implementation of SSI-based learning in the production of bio-foam from sugarcane bagasse demonstrates high competency and adherence to the learning stages. The average score of 87.6 fell into a very good category. The proficiency in completing the SSI-focused worksheets achieved an average score of 89.3; it was also classified as very good. The implementation of an SSI-focused study has led to the attainment of level 4 analytical skills in scientific argumentation for sugarcane bagasse production. This study reveals that students are capable of presenting argumentation skills with a single, clear counterargument. Therefore, implementing SSI-based learning in the production of sugarcane bagasse can enhance the development of scientific argumentation skills.

Keywords: Bio-foam; Scientific Arguments; Socioscientific Issues; Sugarcane Bagasse

Introduction

In the era of the 4.0 industrial revolution, skills are needed that lead people to achieve success in their life. Thus, in the 21st century, students are required to possess skills in creative thinking, critical thinking and problem-solving, communication, and collaboration, commonly referred to as the 4C (Afida, 2023). The 4C skills, including communication skills, can be developed through education in institutions. Communication skills are one of the abilities that students need to convey arguments from observations based on both oral and written analysis activities (Widhi et al., 2021). According to Bricker and Bell (2008), it is also stated that communication skills are the most important process in science learning and can help students achieve a better understanding.

According to Amalia et al. (2019), science is not just about discovering and presenting facts, but also about building

arguments and considering them, as well as debating various explanations of phenomena. Erduran (2004) stated that scientists use argumentation to support theories, models, and explain natural facts. The process of building knowledge in science education involves developing an explanation by creating reasonable data and then presenting it to the community for critique, debate, and revision (Driver, 2000).

Argumentation skills are one of the techniques to showcase students' argumentation in communication skills, which can encourage these students to observe and seek facts and evidence, as well as beliefs. Therefore, these skills emerge from the understanding of concepts, ideas, or situations, allowing students to become accustomed to arguing (Qodriyah, 2018). In addition, Siska et al. (2020) found that students experience difficulties in scientific argumentation. This can be seen when students explain scientific phenomena, such as with the students from Muhammadiyah 3 Senior High School of Yogyakarta, who are still relatively unaccustomed to expressing scientific arguments in the classroom learning process.

In addition, many students still face difficulties in this regard, so teaching needs to start focusing on involving students in scientific argumentation as part of science. (Siska et al., 2020). As well as the difficulties with argumentation, students' analytical skills are at a low standard. Based on the research conducted by Sandoval & Millwood (2005), it was found that high school students in developed countries experience difficulties in constructing scientific arguments and face challenges in explaining scientific phenomena empirically in class discussions.

The low scientific argumentation skills of students are related to the lack of learning experience and the dominance of teachers in the learning process, which results in students' understanding of the material being less profound. As a result, their analytical skills are weak, so their scientific argumentation skills do not develop (Erduran et al., 2005). One way to develop scientific argumentation skills is through learning based on socio-scientific issues. The socioscientific issues approach is an approach that highlights issues or problems that arise within society. Socioscientific issues aim to stimulate intellectual, moral, and ethical development by raising awareness of the relationship between science and social life (Zeidler et al., 2005). In addition, the socioscientific issues approach has the potential to train skills for solving problems faced by students during the learning process. The syntax of examples of socioscientific issues includes information orientation, material review, exploration of ethical values, discussion, statement construction, ethical study, decision-making, and reflection (Aisya et al., 2017).

According to Hanifah et al. (2021), the socio-scientific issues-based learning model has a significant impact on problem-solving abilities using the Powtoon application. According to Afrilya (2020), there is an influence of applying the SSI issues learning approach on students' science literacy skills regarding petroleum material. The research results show that there is a positive influence, which can be observed from the comparison of the t-value and the t-table, with a t-value of -22.942, while the t-table value at a 5% significance level is 2.0301. The improvement in science literacy can be categorised as 'high', as evidenced by an N-Gain value of 0.7352. Other researchers also argue that learning based on SSI issues can enhance students' scientific argumentation skills because when the learning takes place using the SSI issues model, it can present students with a social problem from the perspective of scientific knowledge or scientific background (Siska et al., 2020).

In order to achieve the development of scientific argumentation skills in students, the presence of professional educators is needed so that the learning process can integrate social issues with science material. Therefore, a model of learning approach based on SSI issues is required. One of the social issues that is currently emerging is related to environmental damage caused by

waste, especially plastic waste. Plastic has many benefits for human life. However, plastic derived from the synthesis of petroleum hydrocarbon polymers also has negative impacts on the environment due to its limited quantity, non-renewable nature, and slow decomposition. One example of plastic is styrofoam, which comes from the type of plastic polystyrene (PS). Styrofoam is widely used as a container for various types of food. However, the use of styrofoam is highly discouraged because it has negative plastic properties. Therefore, there is a need to replace styrofoam with food containers made from natural sources such as sugarcane bagasse as a fiber raw material that has the characteristic of being biodegradable in nature (Tibalia, 2024).

The sugar industry can produce bagasse at around 32% of the weight of the milled sugarcane. Sugarcane bagasse, also known as bagasse, is a byproduct of the sugarcane juice extraction process. Sugarcane bagasse mostly contains lignocellulose. The fiber length is between 1,7-2 mm with a diameter of about 20 μm, so this sugarcane bagasse can meet the requirements to be processed into engineered boards. Bagasse fiber is insoluble in water and mostly consists of cellulose, pentosan, and lignin (Bahri et al., 2021). Sugarcane bagasse has a physical appearance that is yellowish, fibrous, soft, and requires a soft place for storage in the form of charcoal in the same quantity. Sugarcane bagasse is a complex lignocellulosic compound. Cellulose is the main component of the structure of woody plant tissues, and this material is also found in shrubs such as ferns, mosses, algae, and fungi.

The addition of protein and fiber is to improve the physical and mechanical properties of the resulting bio-foam. Increasing the fiber concentration can enhance the mechanical properties of the product and reduce the moisture content after the printing process. Increasing the protein concentration can reduce the moisture content after printing, water absorption capacity, and spoilage rate. Therefore, the processing of sugarcane bagasse waste is one of the social issues applied in SSI issues-based learning to develop scientific argumentation skills. The novelty of this research lies in the scientific argumentation skills of students resulting from SSI issues-based learning applied in the production of bio-foam from sugarcane bagasse.

The application of SSI issues-based learning to develop scientific argumentation skills in the production of bio-foam from sugarcane bagasse was conducted with students participating in science extracurricular activities. Through the SSI issues approach, learning not only focuses on scientific concepts but also explores pro and con perspectives related to these issues, creating space for the development of students' critical thinking toward real-world problems (Rahayu, 2019). That is already in line with scientific argumentation skills, which include students' ability to construct coherent arguments, present relevant evidence, and formulate conclusions based on strong logic and scientific evidence.

There are several indicators of scientific argumentation skills, including: a) Claim, which contains a statement or decision believed by the individual making the argument; b) Evidence, which is scientific data that supports the claim; c) Reasoning, which is the justification that connects the claim with the evidence; and d) Rebuttal, which is a statement that opposes the data or an explanation regarding the relationship between the data and the claim (Acar & Patton, 2012). Furthermore, this study applied the learning based on socio-scientific issues. In more detail, the implementation of this learning refers to each phase of the SSI issues-based student worksheet, which is analysed at each stage. The SSI issues-based student worksheet has 5 stages: (1) problem approach and analysis; (2) problem clarification; (3) continuation of the issue; (4) discussion and evaluation; and (5) reflection (Rostikawati & Permanasari, 2016).

Methodology

In this study, a pre-experiment method was used, specifically a one-shot case study, where a group was given treatment and then observed for the results (Creswell, 2012; Sugiyono, 2017). 20 students from Muhammadiyah 3 Senior High School in Yogyakarta participated in this study as part of their science curriculum in 2024. Therefore, the researchers were focused on one class that was given the treatment and observed how students learned SSI to develop their scientific argumentation skills in the application of production of bio-foam (biodegradable styrofoam) from sugarcane bagasse. Furthermore, the researchers conduct this research in three stages: the planning stage, the implementation stage using a learning model, and the concluding step. The following steps that need to be performed are as follows:

1. Planning Stage

The planning stage encompasses a preliminary investigation designed to acquire a comprehensive understanding of the research topic through a literature review, which involves analysing relevant papers related to current or historical social issues and examining educational models grounded in SSI. The students' activities in observation sheets and worksheets were confirmed and revised by subject matter experts. Therefore, a trial was performed for the validation of the instrument.

2. Implementation Stage

The SSI-based learning model guides the conduct of learning activities during the implementation stage. The stages in the learning implementation follow the thinking framework model from Burke et al. (2014), which incorporates science and technology practice in teaching integration. This is achieved by combining the instructional inquiry model from Burke et al. (2014), which combines the instructional 6E steps: consisting of engaging, exploring, explaining, engineering, enriching, and evaluating. Furthermore, this is also achieved by adopting the context of the socio-scientific issue suggested by Zeidler (2016,) which engages students' scientific literacy in science learning.

a. Phase 1: Analysis Issues

During this phase, the teacher instructs students to read and comprehend the discourse, which takes the form of an article in the worksheet. The expectation is that the students will ask questions after reading the article.

b. Phase 2: Clarify Issues

During this phase, the teacher instructs students to gather information from multiple reliable sources under their guidance and to engage in practical activities. The objective is to assist students in responding to the questions presented and sharing these answers with other groups to pinpoint their issues.

c. Phase 3: Identify Social Issues

In this phase, the goal is for students to identify the information from the book or worksheet, identify the connection between articles 1 and 2, and determine how to address or innovate it.

d. Phase 4: Discussion and Evaluation

During this phase, teachers teach students to explore various alternatives for problem-solving, such as the internet, journals, or books, which can aid in formulating answers. Students formulate solutions to existing problems, consult with educators or teachers, and choose solutions based on their guidance.

e. Phase 5: Reflection

Students present the analysis results from each of their groups in this phase, along with arguments backed by credible sources, to which other students respond. After that, the educator provides reinforcement and corrects any incorrect concepts.

3. Concluding Step

At the final stage, students are asked to draw conclusions and analyse the research data related to learning SSI to develop their

scientific argumentation skills in the application of the production of bio-foam (biodegradable styrofoam) from sugarcane bagasse.

The primary data from students participating in science extracurricular activities was utilised within the student scientific group, as well as the secondary data from observation sheets of students' activities and worksheets. In this part, the students were asked to fill out the worksheets while being observed during the learning implementation by using the questionnaire to explore their argumentation skills. The secondary data were directly collected based on data and research results relevant to the application of SSI-based learning, resulting in quantitative data processed statistically. To obtain the primary data, a description of the learning process, observation sheets, and students' worksheets of learning activities are required. Therefore, the students' activities were assessed by identifying the observation sheets and students' worksheets during the learning process and calculating the total scores. Then, the percentage was calculated using the calculation equation (Sugiyono, 2017). It is also possible to learn how to argue scientifically by looking at the level of each indicator on the students' answer sheets using the rubric and the quality level of their written arguments, which were made using Toulmin's Argument Pattern (TAP) and the levels of scientific argumentation quality (Farida 2015) shown in the table below.

Results and Discussion

The results of this study discuss the students' activities during the implementation of a learning model based on SSI activities and show the students' skills of scientific argumentation in the production of sugarcane bagasse, which have achieved level 4 analytical skills. This study shows that application of the instructional 6E model in the SSI context could improve students' scientific argumentation at level 4 of the analytical skills, as shown in Table 2 (Burke et al., 2014; Zeidler, 2016).

The implementation of SSI-based learning consists of five stages: (1) analysing issues; (2) clarifying issues; (3) identifying social issues; (4) discussion and evaluation; and (5) reflection. During the initial phase of learning, problem analysis and clarification are performed. Afterwards, during the second meeting, the stages of learning involve the continuation of analysis of the issues and evaluative discussions. In the third meeting, the stages of reflection and assessments to assess scientific argumentation skills take place, following the Toulmin Argumentation Pattern (TAP), as illustrated in Table 3. Meanwhile, 20 students are organised into four groups during the process of learning, each including five individuals. The outcomes of producing bio-foam (biodegradable styrofoam) from sugarcane bagasse through SSI-based learning formed a total students' score of 87.6 for overall steps of the implementation, which indicated very good results, as illustrated in Table 2. However, most students received good results in the reflection step and lower results in the analysis issues steps, which indicated that students found it hard to think about their argumentation skills. Additionally, the evaluation of activities during SSI-based learning is conducted by an observer assigned to observe students' actions during the learning process. Creswell (2012) incorporates this observer to provide a more accurate and comprehensive depiction of an event or occurrence. The observation method involves straight observation and documentation, devoid of any participation in the experienced event (Hasanah, 2017).

Scientific argumentation skills are analysed through the results of scientific argumentation skills tests. The test is conducted in stage 4: discussion and evaluation in learning. The goal of implementing SSI-based learning is to develop students' abilities in scientific argumentation skills. Classification of categories for the development of scientific argumentation skills based on the level of argumentation quality, referring to TAP as outlined in Table 1. Level of Scientific

Argumentation Quality. Based on the research results, students' scientific argumentation skills can be analysed when students engage in group work through discussions and presentations, focusing on these kinds of students' abilities: (a) presenting arguments clearly from group discussions; (b) answering questions or objections accurately and correctly; and (c) appreciating others' opinions, questions, or objections. The results of the students' performance during the debate are presented in Table 3.

Table 1. Level of Scientific Argumentation Quality

Indicator	Characteristics
Level 0	Argumentation is just a claim.
Level 1	Argumentation consists of arguments in the form of simple claims with opposing claims.
Level 2	If the arguments are in the form of claims accompanied by data, counterclaims, and explanations (reasoning), but do not contain rebuttals.
Level 3	If the arguments contain a series of claims or counterclaims accompanied by data and explanations (reasoning) with occasional weak rebuttals.
Level 4	If the arguments contain claims accompanied by one clearly identifiable and precise rebuttal, one argument contains several claims or counterclaims.
Level 5	If the argumentation is extensive (extended, but still related to the learning material), with more than one clear and precise rebuttal.

Table 2. The Significance of Implementing Student Activities in SSI-Based Learning

No	Implementation Stage	Group Activity Score				Mean	Category
		1	2	3	4		
1	Analysis Issues	78	81	76	78	78.3	Good
2	Clarify Issues	89	92	86	86	88.3	Very good
3	Identify Social Issues	85	85	95	95	90	Very good
4	Discussion and Evaluation	90	95	88	85	89.5	Very good
5	Reflection	90	88	100	90	92	Very good
Average Score						87.6	

Table 3. Students' Scientific Argumentation Skills in the Implementation of SSI

No	Indicator of Argumentation	Aspect of Argumentation	Mean	Category
1	Claim	Ability to present group discussion arguments clearly	92	Very good
2	Evidence and Reasoning	Answer questions or objections accurately and correctly	78	Good
3	Rebuttal	Ability to respect others' opinions, questions, or objections	98	Very good
Average Score			89	Very good

Based on the data in Table 3, it can be concluded that the average achievement of students' scientific argumentation skills falls into the very good category with a score of 89. The prominent aspect of students' performance during argumentation is the third aspect, which is the ability of the study group to appreciate the opinions, questions,

or objections of others. This is related to the indicator of scientific argumentation skills (rebuttal). An example of expressing an opinion during a discussion could be: "I disagree with using sugarcane bagasse as bio-foam because it is quite difficult to find in my area. Perhaps it could be replaced with paper pulp to make it more accessible." On the other hand, another student's opinion is, "I agree with the alternative of sugarcane bagasse as bio-foam because currently the use of styrofoam is very prevalent and causes environmental pollution, like the trash that is everywhere." Therefore, based on the level of scientific argumentation, the student's answer has reached level 4, which is based on claims accompanied by reasons that can be clearly and accurately identified, with one argument containing several claims or counterclaims.

This study is in line with the research by Novianti et al. (2022), stating that students can write claims, supporting data for claims, and justifications to correctly connect them, but are not yet able to write data and support to strengthen the argumentation. Similarly, Skills (2009) divided the components of critical thinking into: (1) analysis and evaluation; (2) evidence; (3) argument; (4) claim and belief; (5) synthesis and creation connection of information and opinion; (6) interpretation of data, reflection, learning experience, and process, which focused on building 21st century skills; (7) content knowledge; and (8) expertise. However, Shaughnessy et al. (2017) explained that the components of interpretation, evaluation, analysis, inference, and explanation could be used to recognise the information of observational inferences and the credibility of the information by using scientific thinking and the logical interrelationship of facts from various experiments.

The analytical results related to each level of learning on the production of bio-foam (biodegradable styrofoam) derived from sugarcane bagasse. The average student's proficiency in completing the worksheets corresponds to the learning phases, as evidenced by a total score of 89.3, classified as very good according to the reference in Table 3. In another hand, the assessment of the quality of students' scientific arguments refers to the categories developed by Farida (2015). The arguments analysed are those produced by students in study groups, either orally through presentations or in writing, based on the results of scientific argumentation skills tests. Therefore, Afrilya (2020) states that learning using SSI aims to involve students in the decision-making process, show students the importance of their decisions, and train them to study a problem thoroughly, including aspects related to students' moral values. This implies that learners must acquire the ability to make decisions and hone practical skills that ultimately align with their moral attitudes.

In general, the ability to speak scientific argumentation abilities of the students are predicated upon their learning groups; however, one learning group that has achieved level 4 is of particular concern. Level 4 argumentation is characterised by the inclusion of numerous claims or counterclaims, each of which is accompanied by a distinct and precise rebuttal (Farida, 2015). The results of the observation indicate that the quality of the arguments that students construct is not substantially affected by the presence of study groups. Only a small number of individuals in each group are capable of articulating their arguments. Subsequently, there is no correlation between students' engagement with their arguments and their decision to establish a group (Hakyolu & Bekiroglu, 2011)

Conclusion

This research has discussed the application of SSI-based learning to develop scientific argumentation skills in the production of bio-foam (biodegradable styrofoam) from sugarcane bagasse. Based on the results, this study can be concluded that students' activities during the SSI-based learning process received an average score of 87.6, categorised as very good. The highest average score occurred in the reflection phase at 92, while the lowest average score occurred in the analysis issues phase at 78.3,

categorised as good. On the other hand, the students' ability to complete the SSI-based Student Work Sheet on the production of bio-foam (biodegradable styrofoam) from sugarcane bagasse received an average score of 89.3, which was classified as very good. The highest average score occurred in the identify social issues phase at 94, categorised as very good, while the lowest score occurred in the analyse social issues phase at 79, categorised as good. However, by implementing a study focused on SSI, it was found that the skills of scientific argumentation in the production of sugarcane bagasse have achieved a level 4 analytical skills, which indicated students' abilities to construct clear arguments. Therefore, the authors recommended that educators or researchers focus on the implementation of SSI-based learning in class activities, especially in the context of science learning, which relates to phenomena in daily lives that students can improve their argumentation skills. However, other researchers could continue to promote SSI-based learning in developing the issues that have been debated and unsolved problems to improve students' 21st-century communication skills, especially argumentation skills as described in this article.

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