



Assessing the Effect of Socio-Scientific Inquiry-Based Learning on Socio-Scientific Decision-Making Skill among Senior High School Students

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Abstract: The use of socio-scientific issues as a context in education is very important because education needs to include interdisciplinary and holistic learning. When dealing with socio-scientific issues, students are expected to be able to make competent decisions. This study was aimed to determine the effect of the Socio-scientific Inquiry-Based Learning (SSIBL) on students' socio-scientific decision-making skill. SSIBL is an inquiry-based learning model that places socio-scientific issues as learning contexts that need to be debated and solved through a series of inquiry processes. This study was a quasi-experimental with a non-equivalent control group design, conducted at senior high school MAN 2 Kota Bima, Indonesia. The target population consisting of all students of grade XI with a total of 254 students. Students of XI IPA 3, 4, 5, and 7 classes were chosen as samples through random sampling. Data were collected through pre-test and post-test of socio-scientific decision-making test, then analyzed using ANCOVA. The results showed that there were significant differences of socio-scientific decision-making between students in the experimental group and students in the control group. The research indicated that the SSIBL model has an effect on increasing the socio-scientific decision-making of students in grade XI MAN 2 Kota Bima.

Keywords: Socio-scientific decision-making, Socio-scientific inquiry-based learning; SSI

Introduction

Socio-scientific issues are complex open-ended problems that embed scientific content and practices into the social issues that occur (Kinslow et al., 2019). The integration of socio-scientific issues as a context in education in schools is very important because education needs to include interdisciplinary and holistic learning (Hancock et al., 2019), with the aim of broadening the context of student knowledge and helping students find connections between one field of knowledge and others (Fang et al., 2019). The most common socio-scientific issues used in science and biology learning, especially in Indonesia, are environmental pollution issues, reproductive system-related issues, and additives (Genisa et al., 2020). Preliminary studies have been carried out at MAN 2 Kota Bima to find out the extent to which socio-scientific

issues are integrated into biology learning. The biology teacher has integrated socio-scientific issues into the reproductive system topic in grade XI, by presenting the issue of promiscuity among adolescents.

The use of socio-scientific issues in class confronts students with a situation where students must be involved in argumentation and decision-making activities (Eggert & Bögeholz, 2010). Therefore, students must be able to critically evaluate existing issues based on their basic knowledge and reasoning skills regarding the various benefits and risks that may arise so as to reach the right decision (Sakschewski et al., 2014). Students are expected to be able to make competent decisions about socio-scientific issues, which mean the decisions must be consistent, aligned, and supported by solid evidence (Khishfe, 2012).

Science educators recognize the importance of teaching socio-scientific decision-making skills to

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increase scientific literacy to students, as the next generation, who will participate in complex decisions in the future (Eggert & Bögeholz, 2010; Grace, 2009; Gresch et al., 2013; Jho et al., 2014; Simon & Amos, 2011). Based on the preliminary study, the biology learning in MAN 2 Kota Bima has not trained students to analyze socio-scientific issues from multiple perspectives, be skeptical of information bias, and reflect on the decisions that have been taken. The results of the socio-scientific decision-making tests in the preliminary study show that the socio-scientific decision-making skill of students in grade XI were categorized as low. Previous research also showed similar results, students' reasoning and decision-making abilities in biology learning in several schools in Indonesia were relatively low (Adinda et al., 2021; Handayani et al., 2020; Maulana & Rochintaniawati, 2021).

According to Fang et al. (2019), the socio-scientific decision-making framework consists of three interconnected phases: (1) identify issues and formulate decision alternatives (pre-selection phase); (2) applying the right decision-making strategy (selection phase); and (3) reflect on the decision-making process. Each phase helping students to develop their socio-scientific decision-making dimensions. There are four socio-scientific decision-making dimensions: (1) collecting and recognizing each option's features based on multiple aspects of evidence or information; (2) making a choice based on multiple aspects' justifications; (3) considering the options using compensatory decision-making strategy; and (4) critiquing decision made by others' from multiple aspects (Zhang & Hsu, 2021).

The decision-making process involves the ability to consider values (value judgment). When faced with socio-scientific issues, students need to consider personal, social, cultural, and scientific values (Christenson et al., 2014; Lee & Brown, 2018). Social and cultural values are obtained from daily life, i.e. family and society (Oktaviyanti et al., 2016) while scientific values are obtained from the inquiry process (Alcaraz-Dominguez & Barajas, 2021).

Scientific inquiry is a core activity in biology learning practices (Asmoro et al., 2020; Kaya & Avan, 2020). Inquiry is a constructivist learning approach that can increase students' scientific knowledge through investigative and exploratory activities (Capps & Crawford, 2013; Jeffery et al., 2016; Lee & Brown, 2018). Through inquiry, students can verify existing information to assist the reasoning process, and use it to discuss their views on real-world problems (Dawson & Carson, 2017; Romine et al., 2020). So, inquiry can be used as an intellectual and methodological tool to evaluate the values and information to be able to reason in reaching the right decision.

Based on the explanation above, to be able to develop students' socio-scientific decision-making, teachers are required to integrate inquiry as a learning approach and SSI as a learning context in class. Therefore, teachers need a guideline that can help them to apply these approaches and contexts in learning in the form of learning models. The learning model that integrates SSI with inquiry is the Socio-Scientific Inquiry-Based Learning (SSIBL) learning model.

The Socio-scientific Inquiry-based Learning (SSIBL) was developed by Levinson et al. (2017) aims to find answers to various confusing socio-scientific questions and by applying science, technology, engineering, and mathematics (STEM) approaches to challenge the younger generation. SSIBL is a practical tool for improving teacher teaching practice, linking real-world developments in terms of science and technology, and encouraging young people to make changes in the real world.

Students need experience and practice to develop justifications for their claims, identify and overcome conflicting arguments, and study material that can strengthen arguments in order to be able to make informed decisions. Teachers need curriculum resources that are relevant and can involve students in debate and argumentation activities (Gutierrez, 2015). The application of SSIBL learning in the classroom provides a convergence point in prohibiting various components of scientific literacy (Sadler, 2013) and provides opportunities for students to explore the relationship between science and life through topics that are discussed, discussed, and debated (Cook & Buck, 2017).

The application of the SSIBL model in learning is in line with previous research. Ariza et al. (2021) explained the theoretical foundation of integrating SSIBL as a relevant strategy within school curricula. Eastwood et al. (2013) claimed that the SSI context contributes to a deep understanding of the concept of inquiry that is interdisciplinary and problem-centered. Suwono et al. (2021) claimed that the application of Interactive Socio-scientific Inquiry as an learning approach increase students' scientific literacy, biology knowledge, and critical thinking skills. To the best of the authors' knowledge, no published study was found that specifically focused on the effectiveness of SSIBL on high school students' socio-scientific decision-making skill. Therefore, this research aims to assess the effect of Socio-scientific Inquiry-Based Learning (SSIBL) on socio-scientific decision-making skill of senior high school students.

Method

This research work adopted a nonequivalent pre-test-post-test control group design, a randomized experimental design consists of experimental group and control group. Experimental group was exposed with SSIBL and control group was exposed with guided inquiry-based learning (GIBL), the learning model that is usually applied by the teacher. This study involves the learning models (SSIBL and GIBL) as independent variables and socio-scientific decision-making skill as dependent variables. This study was conducted at senior high school MAN 2 Kota Bima, Indonesia, with a target population consisting of all students of grade XI with a total of 254 students. Students of XI IPA 3, 4, 5, and 7 classes were chosen as samples through random sampling, Class XI IPA 3 (n= 40) and 4 (n= 38) were selected as the control group (guided inquiry learning) while Class XI IPA 5 (n= 37) and 7 (n= 38) were selected as the experimental group (SSIBL).

Learning activities carried out in biology course within 8 weeks' time periods. Socio-scientific issues discussed are related to human circulatory and digestive system: (1) Smoking addicted teenager in Indonesia; (2) Heart xenotransplantation from pig to human; (3) The prevalence of stunting in Indonesia; (4) Viral snacks that cause food poisoning. Application of SSIBL consist of seven educational stages developed by Knippels et al. (2018) that are introduction of dilemma, initial opinion-forming, raise questions, inquiry, dialogue, decision-making, and reflection. GIBL model refers to Asmoro et al. (2020) with seven learning stages that are exploring phenomena, making a question, planning an investigation, carrying out investigation, analyzing data, build new knowledge, and communicating new knowledge.

Students' Socio-scientific Decision-making skill data were collected through pre-test and post-test, using measurement instruments adapted from Sakschewski, et al. (2014). The instruments have been tested for validity and reliability. The scoring refers to Zhang et al. (2021) that categorized socio-scientific decision-making into four levels of dimensions: (1) Collecting and recognizing each option's features based on multiple aspects of information; (2) Making a choice based on multiple aspects' justifications; (3) Considering the options using a compensatory decision-making strategy; (4) Critiquing decision made by others from multiple aspects.

Data collected from the study were analyzed using analysis of covariance (ANCOVA). ANCOVA was performed used to determine whether there is a significant difference of socio-scientific decision-making score between students who were exposed to the SSIBL

and students who were exposed to GIBL. the interaction effects of learning models (SSIBL and GIBL) on students' socio-scientific decision-making (post-test score), by controlling the effect of pre-test score as covariant (Longford, 2010). ANCOVA requires the fulfillment of the normality, homogeneity of variance, and homogeneity of regression slopes assumptions. The normality assumption was examined using Kolmogorov-Smirnov Test, the homogeneity of variance was examined using Levene's test of equality of variance, and the homogeneity of regression slopes using two-way ANOVA.

Improvement in socio-scientific decision-making can be identified by analyzing the N-gain (Normalized gain) score based on the results of the pre-test and post-test. N-gain score categorized as shown in Table 1.

Table 1. N-Gain Score Categories (Hake, 1999)

Score	Categories
$g > 0.7$	High
$0.3 < g \leq 0.7$	Medium
$g \leq 0.3$	Low

Result and Discussion

The assumptions of normality, homogeneity of variance, and homogeneity of regression slopes have been checked prior to ANCOVA. Kolmogorov-Smirnov test's result showed that the data was normally distributed. The result of Levene's test showed that variance for the two groups is similar. The homogeneity of regression slopes showed that no interaction between the covariate and the treatment. Hence all of the assumptions were satisfied, an ANCOVA was performed to compare the students' socio-scientific decision-making skill between SSIBL group and GIBL group. The results shown in Table 2 reveal that there is a statistically significant difference between students' socio-scientific decision-making skills in the SSIBL group and GIBL group ($F = 337.29$; $p = .00 < 0.05$. Pre-test score was significantly take effect on the post-test ($F = 298.27$; $p = .00 < 0.05$).

Table 2. Analysis of Covariance (ANCOVA) of Students' Decision-Making Score in SSIBL and GIBL

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1977.18	2	988.59	226.71	.00
Intercept	3445.67	1	3445.67	790.17	.00
Group	1470.83	1	1470.83	337.29	.00
Pre-test	1300.66	1	1300.66	298.27	.00
Error	1321.29	303	4.36		
Total	16188	306			
Corrected Total	3298.47	305			

SSIBL effectiveness is described through the N-gain score shown in Table 3. It reveals that N-gain score of students in the SSIBL group was higher than one in the GIBL group. N-gain score of the SSIBL group was 0.66 which categorized as medium, N-gain score for GIBL group was 0.35 also categorized as medium.

Table 3. N-Gain Score

Group	N-Gain Score	Category
SSIBL	0.66	Medium
GIBL	0.35	Medium

In addition, this study also analyzed the improvement of each socio-scientific decision-making dimension of students after exposed to the SSIBL and GIBL. The improvement analyzed through N-gain that shown in Figure 1.

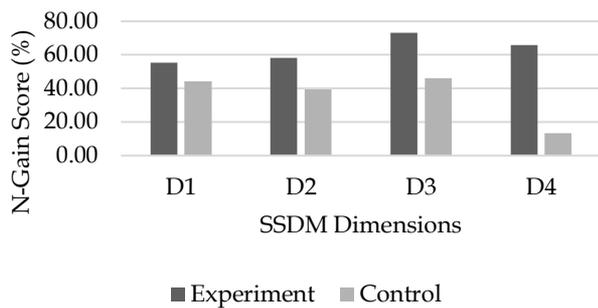


Figure 1. The N-gain score for each dimension of socio-scientific decision-making

- D1: Collecting and recognizing each option’s features
- D2: Making a choice based on multiple aspects’ justifications
- D3: Considering the options using compensatory decision-making strategy
- D4: Critiquing decision made by others from multiple aspects

Referring to Figure 1, the N-gain of each dimension of socio-scientific decision-making of the experimental group was higher than the control group. In experimental group, D3 has the highest N-gain followed by D4, D2, and D3. In control group, D3 also has the highest N-gain followed by D1, D2, and D4.

Based on the result, this study suggested that the socio-scientific decision-making score of students who were exposed to the SSIBL was significantly better than the decision-making score of their counterpart who were exposed to GIBL. This finding is in line with the studies of Sheira (2023). The difference score between two group was occurred because of the learning syntax of SSIBL encourages students to develop their decision-making skill.

The first and the second SSIBL learning stages are the introduction of dilemmas/problems and the initial opinion formation stage. Teacher start the classroom

practice by introducing dilemma that related to human circulatory and digestive system. Students engaged with the issues being introduced which lead them to curiosity, which corresponds to the first phase of socio-scientific decision-making, the pre-selection phase. The pre-selection phase of decision-making requires students to identify the problem to be solved and identify various possible options.

The third and fourth SSIBL learning stages are asking questions and inquiry. These stages can help students to develop first-dimensional socio-scientific decision-making abilities, collecting and identifying the pros and cons of each option based on various aspects of evidence and information. Through ‘ask’ and inquiry activities, students develop an understanding of biological concepts that can explain problems from a scientific point of view. Understanding of concepts is the main basis for decision-making (Eastwood et al., 2013; Liu et al., 2011). Students are also asked to make questions about social perspectives about the issues. The results of the inquiry activity are used to formulate options with the pros and cons of each of them. In the topic of circulatory system with the issue of smoking addicted teenager, questions were asked by students such as "Is vape better than conventional cigarettes in terms of circulatory health?" By answering these questions, students can find out the pros and cons of vape. The pro is the vape does not produce combustion smoke like cigarettes, but vape liquid contains chemicals that are no less dangerous. In the material on the digestive system with the issue of viral snacks, one of the questions asked by students was "Does the ban on viral snacks affect the emergence of various other food processing technology innovations in the future?". By answering these questions, students can find out various other food processing technologies that are safer and can be an option for solving problems.

The fourth SSIBL learning stage is the dialogue, which is a forum for students to communicate and clarify the results of inquiry and formulate solutions. Through this dialogue activity, students can practice first-dimensional decision-making skills, recognizing the pros and cons of each option based on multiple aspects. Since each group have different information about each options’ pros and cons, so students also involved in the debate activity. Each group presents its arguments and tries to defend their opinion. Putri, Siahaan, & Hernani (2020) suggested that inquiry model based on SSI can support students’ argumentation abilities. According to Siribunnam et al. (2014), debate can be used as an approach to increase understanding of socio-scientific issues and encourage students to think critically which leads to better decision-making. Walpuski et al. (2012) also argues that decision-making

competence is highly dependent on the frequency with which students are given opportunities to debate during science lessons in class. This study also in line with study of Sakamoto et al. (2021) that the instruction, which emphasized generating solutions to resolve issues, promoted students' socio-scientific decision-making.

Based on discussion above, the first five stages of SSIBL learning all focus on pre-selection phase of socio-scientific decision-making, where students gathering and identifying the pros and cons of each option. This is in accordance with the theoretical framework of socio-scientific decision-making by Fang et al. (2019), that socio-scientific decision-making is more than just the act of making decisions. Instead of focusing on the end product (i.e. phase 2 and phase 3), socio-scientific decision-making is considered a multi-phase process that also includes decision preparation (SSI negotiation; phase 1), decision-making strategy selection (option evaluation; phase 2), and reflection (phase 3).

The sixth stage of SSIBL is decision-making, which is the practice of the second decision-making phase, namely the selection phase. The selection phase consists of two tasks, the decision-making task and the reflection task. The decision-making task helps students develop two dimensions of decision-making, the second and third dimensions. The second dimension is making a choice with consideration of various aspects. When discussing about socio-scientific issue, i.e. the prevalence of stunting in Indonesia, students are asked to choose which food options should be provided at the '*Posyandu*' (The integrated healthcare center in Indonesia) to be given to toddlers. A group of students states that the important aspect to consider is the high content of animal and plant-based protein, carbohydrates, and fats so they choose a diet rich in these three ingredients.

The third dimension is using a compensation strategy. Based on the results of students' worksheet on the circulatory system topic, students are still not able to apply decision-making strategies properly. Garrecht et al. (2020) claimed that to improve the selection phase of decision-making requires step-by-step instructions. Therefore, in the second cycle of SSIBL, digestive system topic, students are taught step-by-step to use decision-making strategies, especially for compensation strategies. So that in the next worksheet and when doing the posttest students begin to be able to apply the compensation strategy well, it shows in the Figure 2 that N-gain score of experimental group for the third dimension is the highest.

The second task of the selection phase is the reflection task. The dimension of socio-scientific decision-making that is trained in this phase is to criticize the decisions of other groups from multiple aspects. When students are asked to criticize, they find it

difficult to criticize decision-making with compensatory strategies compared to non-compensatory strategies. When asked to criticize decisions made by others, students need to explain the weakness of the selected options (Zhang & Hsu, 2021), because one of the characteristics of socio-scientific issues' solution is it always comes with pros and cons (Fang et al., 2019). This study is supported by Grace (2009) that there are three keys obtained from groups of students who have high quality socio-scientific decision-making, including: (1) teachers who facilitate the reflection process by asking questions that provoke students' thoughts; (2) the contribution of science content knowledge; and (3) the availability of information that can be used to clarify the pros and cons of certain options.

Based on the N-gain score, students' socio-scientific decision-making in control group was lower comparing to the one in experiment group. Guided inquiry-based learning encourages students to collect information about problems to solve it, but the learning stages does not involve debate and decision-making practice. This results supported by Papadouris & Constantinou (2010), students cannot determine the right decision-making strategy because students are not equipped with decision-making abilities.

Conclusion

The implementation of the SSIBL has an effect on students' socio-scientific decision-making skills. The dimension of socio-scientific decision-making that was most affected by the SSIBL model is using a compensation strategy to consider each option. So, SSIBL can be used as an alternative learning model to enhance students' socio-scientific decision-making.

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Research design, instrument preparation, research implementation, data collection and analysis, and article writing, Maryam; guiding the entire research process, proofreading, Hadi Suwono. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest

The authors declare no conflict of interest regarding the publication of this paper.

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