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The Effectiveness of the Socio-Scientific Issues-Based Experiential Learning Model (SSI-ELM) to Improve Decision-Making Skills in Biology Education Students

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ABSTRACT The SSI-ELM-based experiential learning model is a strategy that emphasizes experience grounded in the SSI context. The integration between the EL and SSI models provides authentic learning experiences related to SSI, thereby training students to develop effective decision-making skills. This study aims to test the application of the Experiential Learning model based on socio-scientific issues (SSI-ELM) in an effort to improve decision-making skills in prospective biology teacher students. This study uses a quasi-experimental method with Pretest-Posttest Comparison Group Design. The subjects of the study consisted of 129 students divided into two classes, namely the experimental class (n = 66) and the comparison class (n = 63). Research data were collected using test instruments (decision-making ability tests) and non-tests (questionnaires and structured interviews) to dig deeper information on the research subjects. The research data were analyzed using quantitative and qualitative data analysis techniques to describe the data findings. The results of the study indicate that the application of the SSI-ELM model can improve the ability of biology students to make decisions with an effective category. The indicator of decision-making ability achievement in the experimental class (SSI-ELM) is higher than the comparison class (inquiry and PjBL). The results of this study recommend SSI-ELM as an effective alternative model for equipping biology students with decision-making skills.

Keywords Experiential learning, Socio-scientific issues, Decision making

1. INTRODUCTION

Biology education in the 21st century is expected to equip students with various skills, especially related to 21st-century biology abilities, which include critical thinking, creative thinking, communication, collaboration, and problem solving (Trilling & Fadel, 2009). One of the essential skills that students must also have is the ability to make arguments and decisions (Erduran & Msimanga, 2014). This ability is crucial for prospective biology teachers because they will face various situations inside and outside the classroom that require careful consideration and appropriate decision-making amidst the massive and rapid flow of information (Sakamoto, Yamaguchi, Yamamoto, & Wakabayashi, 2021; Menon & Sadler, 2016). In everyday life, the decision-making ability enables individuals to participate actively and responsibly in social and environmental issues related to biology, the environment, and climate change (Fowler et al., 2016; Zeidler & Newton, 2019). Biology education students decision-making ability still needs to be improved. Traditional biology teaching that often focuses on passive knowledge transfer provides students with fewer opportunities to develop critical and analytical thinking skills that underlie effective decision making (Quitadamo, Faiola, Johnson, & Kurtz, 2008; Patronis, Potari, & Spiliotopoulou, 1999). Students can memorize facts and concepts, but they have difficulty applying them to the situations that require various considerations (Zohar & Nemet, 2002).

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Several studies to explore various effective methods in developing decision-making skills in students, such as the problem-based learning method, inquiry, and project-based learning, found potential in developing thinking and decision-making skills in students (Qamariyah, Rahayu, Fajaroh, & Alsulami, 2021; Satria et al., 2024). According to (Cebesoy, 2020) decision-making skills are influenced by experiences in everyday life. Therefore, an experiential learning model based on the ability integrated with SSI is very appropriate to be applied to improve decision-making skills in students. EL is a learning process that connects the theory given in class with real environmental situations. EL involves learners in direct experience and focused reflection, and it aims to increase knowledge, develop skills, clarify values, and improve community capacity to contribute to the community (Association for Experiential Education, 2021).

Previous studies that combine experiential learning and SSI generally focus on developing conceptual understanding of science, argumentation skills, and views on the nature of science (Khishfe, 2012; Qamariyah, Rahayu, Fajaroh, & Alsulami,, 2021; Satria et al., 2024). Although these skills contribute to decision-making skills, studies that explicitly measure and analyze the impact of integrating the experiential learning model with the SSI approach on improving decision-making skills in biology education students have not been widely studied. The implementation of SSI in several countries has shown positive results in improving student competencies in the era of the Revolution 4.0 (Genisa, Subali, Djukri, & Habibi, 2021); improving the quality of argumentation, information reasoning, conceptual understanding (Venville & Dawson, 2010), decision making (Hsu & Lin, 2017) and reflective assessment (Zeidler, Sadler, Applebaum, & Callahan, 2009a).

Based on the research background described, this study is very relevant to be conducted for various reasons. First, this study will specifically test the effectiveness of a learning model that integrates experiential learning with socio-scientific issues (SSI-ELM) on improving the decision-making ability of biology education students. Second, this study is expected to provide empirical contributions to developing innovative learning models relevant to the demands of the 21st century and the needs of prospective biology teachers. Third, the results of this study can be the basis for constructing a more effective biology curriculum and learning practices in equipping students with the ability to make decisions crucial for their professional careers and personal lives. Fourth, this study was conducted in the context of higher education in Indonesia, and thus the results will provide insights relevant to the characteristics and challenges of the education system in this country.

This study aims to answer the main research question: Is the experiential learning model based on socio-scientific issues effective in improving decision-making skills in biology education students? In other words, it is expected to find empirical evidence regarding the superiority of the SSI-ELM model in developing this important ability in biology education students, so that it can provide positive implications for improving the quality of biology education in Indonesia.

2. METHOD

2.1 Design

This study used a quasi-experiment method with Pretest-Posttest Comparison Group Design (Fraenkel & Wallen, 2006). The study design is presented in Table 1.

Table 1 Research design

Class	Pre-test	Treatment	Post-test
Experiment	O_1	T_1	O_2
Control 1	O_1	T_2	O_2
Control 2	O_1	T_3	O_2

As for what is meant by O_1 = implementation of pre-test; T_1 = Treatment using SSI-ELM; T_2 = Treatment using Inquiry; T_3 = treatment using PjBL; O_2 = implementation of post-test

Based on Figure 1, it can be explained that this study involved one experimental group and two comparison groups. Prior to the treatment, all groups had their initial ability measured through a pre-test (O_1). Then, the experimental group received a specific treatment (T_1), comparison group 1 received another treatment (T_2), and comparison group 2 received a different treatment (T_3). After the treatment is complete, the ability of all groups is again measured through a post-test (O_2). The post-test results between groups will be compared, taking into account the pre-test results, to analyze the effectiveness of each treatment.

2.2 Research Subjects and Interventions

The subjects of the study were students of semester I and semester V of Biology Education, Universitas Islam Negeri Siber Syekh Nurjati Cirebon consisting of two regular classes (n=63) and two experimental classes (n=66) with the following details.

Table 2 Distribution of research subjects and fields of study

Class	Treatment	Semester	Subjects	SSI Study
Experiment	SSI-ELM	I	32	Pollution
		V	34	Mangrove
Control	Inquiry	I	32	Pollution
	PjBL	V	31	Mangrove

The research interventions conducted were divided into two classes, namely the experimental class and the comparison class. The experimental class was divided into two classes consisting of biology students in semester I and semester V with the intervention of SSI-ELM implementation. The control class was divided into two classes consisting of biology students in semester I and semester V with the intervention of inquiry

implementation (semester I) and PjBL implementation (semester V).

Students from Semester 1 and Semester 5 were selected for this research based on several considerations: the materials course is relevant to the context of SSI in general biology courses, specifically in the environmental pollution chapter (Semester 1) and the coastal/mangrove ecology chapter (Semester 5), their academic abilities, and a homogeneous number of students. The interventions conducted followed the syntax of SSI-ELM, inquiry, and PjBL in Table 3.

Table 3 shows the syntax of the three models used in this study, namely SSI-ELM, inquiry, and PjBL. The SSI-ELM model used in this study adopts the syntax development results of SSI based learning. The following are the phases and explanation of each stage in the SSI-ELM model used in this study.

Based on Table 4, the SSI-ELM stages and descriptions related to each stage are known. The following figure explains the stages in an ecology course using SSI-ELM.

Figure 1 shows the implementation of SSI-ELM in ecology lectures. The SSI-ELM approach not only emphasizes mastery of science concepts but also trains analyzing, evaluating, and decision making related to social issues in this case in the context of ecology. In its implementation, SSI-ELM learning can be done through debates, simulations, case studies, and mini research activities. In this study, it was carried out through ecological mini research activities. SSI-ELM activities will encourage students to collect data, identify findings, consider each data, analyze data carefully, consider various consequences so that they can make the right decision.

2.3 Instrument

This study used the main instrument in the form of a decision-making skills test. This instrument consists of 16 multiple-choice reasoned questions developed from Bloom's taxonomy C5 (evaluating), with a scoring technique of 0, 1, 2, 3. The test questions used have gone through various tests and have been declared valid and reliable. The dimensions of the cognitive process in the decision-making skills test questions consist of checking and criticizing indicators with a distribution in Table 5.

Based on Table 5, it can be seen the distribution of decision-making ability tests that measure the cognitive process of evaluation (C5) by dividing the dimensions/sub-knowledge into factual, conceptual, and procedural, and categorizing the questions into "Checking" (numbers 1-8) and "Criticizing" (numbers 9-16).

Table 3 Syntax of SSI-ELM, inquiry and PjBL

No.	SSI-ELM	Inquiry	PjBL
1.	SSI Orientation	Ask deep questions about natural phenomena.	Determining the fundamental questions
2.	Determining SSI problems	Formulate the problem	Create product design planning
3.	Determining the SSI hypothesis	Formulate hypotheses	Create a product manufacturing schedule
4.	Designing SSI exploration	Design investigations, including experiments	Monitoring student performance and project progress
5.	SSI Exploration	Doing experiments	Outcome assessment
6.	Information analysis	Synthesize knowledge	Evaluation of learning experiences
7.	SSI Generalization		
8.	Decision-making		

Table 4 Syntax of SSI-ELM

Syntax of SSI-MEL	Description
SSI Orientation	Read and check the factual, conceptual and procedural dimensions contained in the given SSI issue. The process of searching and finding data from the given SSI issue
Determining SSI problems	Determine the problem resulting from the review of issue data from the given SSI
Determining the SSI hypothesis	Identify and formulate the relationship between factual, conceptual, and procedural from the given SSI based on the formulation of the problem make a hypothesis
Designing SSI exploration	Design evaluation questions (checking and critiquing) through the 5WH Questions approach - operational verbs to test hypotheses
SSI Exploration	Explore the SSI by answering the evaluation questions (checking and critiquing) that have been created.
Information analysis	Analyze SSI in discourse based on other scientific sources
SSI Generalization	Develop conclusions related to the SSI presented
Decision-making	Making decisions from experiential learning

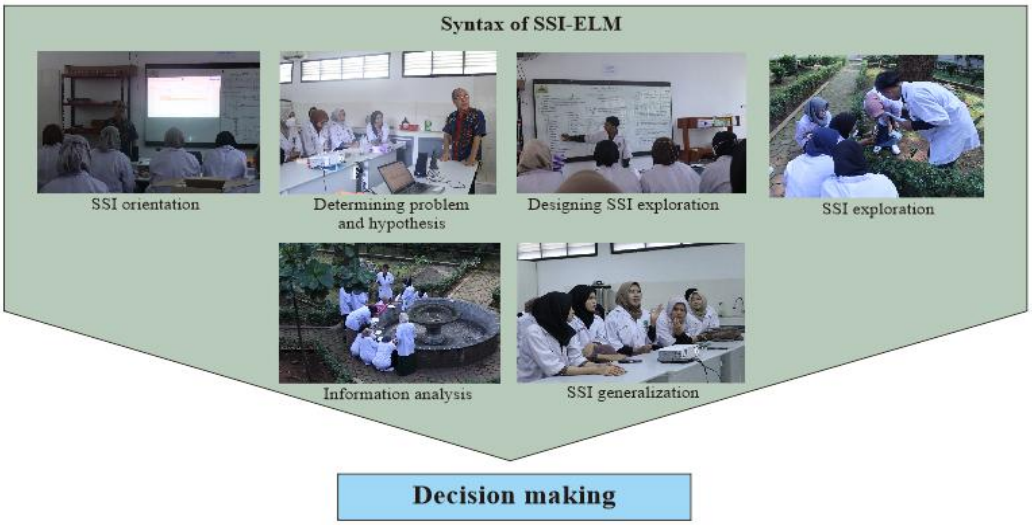

Figure 1 Implementation sytax of SSI-ELM

Table 5 Distribution of decision-making ability tests

Cognitive Process of Evaluation (C5)															
Checking								Criticizing							
Dimensions/Sub Knowledge								Dimensions/Sub Knowledge							
Factual		Conceptual			Procedural			Factual		Conceptual			Procedural		
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16

Table 6 Distribution of decision-making ability test indicators

Cognitive Dimension	Cognitive Process Evaluation (C5)											
	Check						Criticize					
	Orientation	Hyphotesis	Exploration Design	Exploration	Analysis information	Generalization	Orientation	Hyphotesis	Exploration Design	Exploration	Analysis information	Generalization
Factual	√	-	√	√	√	-	-	√	√	√	√	√
Conseptual	√	-	√	√	√	-	-	√	√	√	√	√
Procedural	√	-	√	√	√	-	-	√	√	√	√	√

Based to Table 6, it is shown that the distribution of test indicators for decision-making ability, specifically for the cognitive process of evaluation (C5), links the cognitive dimensions (factual, conceptual, procedural) with specific indicators within "Checking" (orientation, hypothesis, exploration design, exploration, information analysis, generalization) and "Critiquing" (orientation, hypothesis, exploration design, exploration, information analysis, generalization), marked with a checkmark (√) to indicate the relationship between the cognitive dimensions and the decision-making indicators.

2.4 Data Analysis Techniques

The research data obtained were then analyzed with the stages of data prerequisite testing (normality and homogeneity), descriptive statistical testing, inferential statistical testing, and effectiveness testing using normalized gain (N-gain) with the following formula.

$$\langle g \rangle = \frac{S_{posttest} - S_{pretest}}{S_{maks} - S_{pretest}}$$

(Meltzer, 2002)

To determine the effectiveness criteria for SSI-ELM-based learning, the N-gain criteria index is used with the provisions in Table 7.

Table 7 *N-gain index*

Score g (%)	Index	Description
$g > 0.70$	High	Effective
$0.30 \leq g \leq 0.70$	Medium	Quite effective
$g < 0.30$	Low	not effective

(Modification of Meltzer, 2002)

2.5 Research procedures

The implementation of this research is divided into three stages, namely the initial stage in the form of preliminary research activities and needs analysis, implementation, and the final stage of research in the form of measuring the impact of the treatment provided. The research procedure is presented in Figure 2.

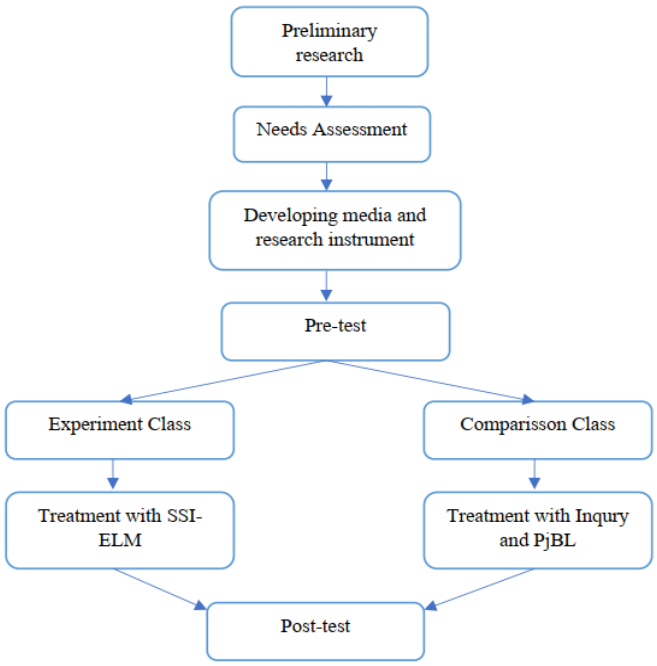

Figure 2 Research procedure

Figure 2 shows the stages of SSI-ELM research starting from preliminary research. The results of preliminary research are used as a reference in the development of needs analysis and development of media and research instruments. The next stage is to conduct a pre-test and provide treatment and measurement of the impact (post-test) of the implementation of the treatment.

3. RESULT AND DISCUSSION

3.1 Result

This study aims to examine the application of Experiential learning model based on socio-scientific issues (SSI-ELM) in an effort to improve decision-making skills in biology teacher candidates. In its implementation, this research was conducted through a quasi-experimental method involving one experimental class and two control classes. The results showed the achievement of decision-making skills in the experimental class and control class. The test results show that there is an increase in the achievement of a higher average test score in the experimental class. For more details on this achievement, see Table 8.

Table 8 shows the achievement of decision-making ability in the experimental class in semester I and semester V showing a higher average score achievement than the comparison class. The experimental class in semester V obtained the highest average score compared to the treatment in other classes. This can be interpreted that the treatment carried out in the experimental class in semester V resulted in better effectiveness. To find out the achievement of each decision-making ability indicator in more detail, it is presented in Table 9.

Table 9 shows the achievement of each indicator of decision-making ability in the experimental class showing superior achievement than the comparison class. The test data shows that the data is normally distributed and homogeneous so that the next testing stage is to use parametric statistical tests and effectiveness tests using the N-gain test presented in Table 10.

Table 10 shows that the learning treatment carried out in both the comparison class (Inquiry and PjBL) and the experimental class (SSI-ELM) had a significant impact on the achievement of decision-making skills in students. The results of the learning effectiveness test used through the N-gain test showed that SSI-ELM applied to semester V students was more effective in equipping students in practicing decision-making. To see the achievement of decision-making skills based on gender is presented in Figure 3.

Table 8 Achievement of decision-making skills scores

Semester	Class	Treatment	Class	Score			
				Lowest Value	Medium Value	Average	Standard deviation
I	Experiment	SSI-ELM	Pre-test	33	58	48.65	± 5.732
			Post-test	65	100	**75.80**	± 7.945
	Control	Inquiry	Pre-test	38	69	49.80	± 6.224
			Post-test	56	77	**67.45**	± 6.074
V	Experiment	SSI-ELM	Pre-test	44	88	55.21	± 9.685
			Post-test	79	100	**88.09**	± 6.154
	Control	PjBL	Pre-test	44	75	56.79	± 7.394
			Post-test	58	98	**78.49**	± 9.939

Table 9 Decision-making skills achievement indicators

Semester	Class	Treatment	Class	Decision Making Indicator	
				Critizing	Checking
I	Experiment	SSI-ELM	Pre-test	53.38	47.14
			Post-test	**77.88**	**76.75**
	Control	Inquiry	Pre-test	46.38	50.43
			Post-test	**66.25**	**63.25**
V	Experiment	SSI-ELM	Pre-test	53.88	51.43
			Post-test	**82.50**	**86.63**
	Control	PjBL	Pre-test	53.13	53.00
			Post-test	**73.13**	**72.87**

Table 10 Statistical test results

Semester	Class	Treatment	T-Test		N-gain Test	
			Sig. Value (2-tailed)	Description	N-gain Value	Description
Semester I	Experiment	SSI-ELM	0,000	Different	0.53	Quite Effective
	Control	Inquiry		significantly	0.34	Quite Effective
Semester V	Experiment	SSI-ELM	0,000	Different	0.71	**Effective**
	Control	PjBL		significantly	0.51	Quite Effective

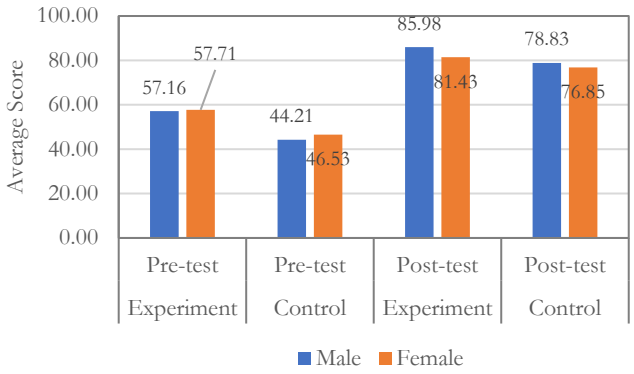

Figure 3 Achievement of decision-making ability based on gender

Figure 3 shows that gender does not contribute quantitatively to the decision-making ability of biology students. Males and females have the same decision-making ability related to SSI in biology lectures on the concept of environmental pollution and mangroves.

3.2 Discussion

The results of this study found that the implementation of SSI-ELM has better effectiveness compared to learning in comparison classes (inquiry and PjBL). The results of N-gain testing showed that the achievement of the experimental class that applied SSI-ELM obtained a higher increase (0.53 and 0.71) than the control class (0.34 and 0.51). The effectiveness test results show that the SSI-ELM model is more effective than the control class. Furthermore, this study found various fundamental findings in the implementation of SSI-ELM at the university level, including: the first finding, the implementation of SSI-ELM in the early semester has a fairly effective impact on decision-making skills in students. This result is different for students in semester V. The implementation of SSI-ELM is considered effective in improving decision-making skills in biology students in semester V. The second finding, the achievement of decision-making ability indicators, both in the experimental class of early semester students (semester I) and in the upper semester students (semester V) showed higher results than the comparison class that implemented inquiry and PjBL.

Based on the first findings in this study, it can be interpreted that the application of SSI-ELM in an effort to improve decision-making skills will be more effective if carried out on high-level students (in this study in semester V). This is because the decision-making process can be influenced by cognitive, affective, and experiential factors (Feng, Han, Zheng, & Kamran, 2022). Biology students in semester V already have basic knowledge of biology and sufficient learning experience so that they are able to develop their reasoning in making better decisions than early semester biology students. In SSI-ELM, this condition is known as reflective judgment, namely the ability to reflect on a decision based on various considerations and information.

SSI-ELM is a learning model that integrates experiential learning with socio-scientific issues. This model is designed to improve students' ability to make complex decisions that are relevant to the real-world context. In this study, fifth semester students have gained more complex learning experiences, such as: practical activities, field lectures, mini research, observation and classroom learning so that they can influence decision making. SSI-ELM emphasizes authentic and meaningful learning experiences. Students not only learn theory, but also engage in simulations, case

studies, or debates that allow them to experience firsthand the complexity of decision making in a socio-scientific context (Lee, 2007; Sakamoto, Yamaguchi, Yamamoto, & Wakabayashi,, 2021). This is the basis for the decision-making ability of fifth semester students to be better than first semester students.

The comparison class students in this study used the inquiry and PjBL models, which in terms of context, both learning models have several similarities with SSI-ELM. However, both models do not make the learning experience and SSI context an important part that is integrated into the learning process. The two models used as comparisons still contribute to the development of decision-making skills, but are less effective in training these skills because they emphasize the context of science itself.

The implementation of SSI-ELM explicitly raises controversial and complex issues related to science and society. These issues encourage students to consider multiple perspectives to reach a consensus, values, and consequences of the decisions taken (Wu & Yang, 2024). SSI-ELM not only trains students in choosing the 'right' solution, but also in considering the ethical, social, and environmental aspects of the decision. This model encourages students to develop critical, creative, and collaborative thinking skills in decision making (Gutierez, 2015; Dusturi, Nurohman, & Wilujeng, 2024).

SSI-ELM offers an integration of social issue-based learning experiences that are not available in the inquiry and PjBL models. This advantage makes SSI-ELM technically an appropriate alternative in developing decision-making in students compared to the inquiry and PjBL models. SSI-ELM also trains students to develop five dimensions of SSI-based reasoning, namely recognizing complexity, analyzing multiple perspectives, continuous inquiry, using skepticism, and community involvement (Ben-Horin, Kali, & Tal, 2023). The five dimensions of reasoning are well trained through the implementation of SSI-ELM.

The implementation of SSI in general also trains the ability to argue and debate which trains students to make decisions appropriately and argumentatively (Marandino, Leite, & Colombo, 2023). SSI-ELM facilitates students in the development of critical thinking skills, moral reasoning, and perspective taking so as to encourage learning to be able to practice social awareness and responsibility for issues facing society, which is the foundation in developing decision-making skills in students (Lee, 2007; Hsu & Lin, 2017; Wang, Schmidt-Crawford, & Jin, 2018).

This is in line with the second finding of this study, namely the achievement of the decision-making ability indicator in the experimental class is better than the control class. This finding explains that the implementation of SSI-ELM is more appropriate in training decision-making skills as per the research results of Ghazal, Boujaoude, & Hokayem (2024); Sutter et al., (2019); Wahono et al., (2021) which shows that the application of SSI in learning can promote the ability to make decisions more deeply than other learning models. A person's knowledge, experience, and perspective will influence the decision-making process (Zeidler, Sadler, Applebaum, & Callahan, 2009b).

4. CONCLUSION

The implementation of the Experiential Learning Model Based on Socio-Scientific Issues (SSI-ELM) has proven effective in improving decision-making skills in Biology Education students at the Universitas Islam Negeri Siber Syekh Nurjati Cirebon. The results of the study showed that students who took part in learning with the SSI-ELM model experienced a significant increase in their decision-making skills compared to students who took regular learning. The regular model commonly used in lectures makes a positive contribution to training students' decision-making skills, but is less effective in training these skills holistically than SSI-ELM. Based on this study, it is known that the application of SSI-ELM is more effective in higher semester students than in the early semesters. This study provides an important contribution to the development of effective learning models to improve students' decision-making skills. SSI-ELM can be an attractive alternative for educators who want to prepare students to face complex challenges in the modern era.

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