

CAN SOCIO SCIENTIFIC ISSUES-DISCOVERY LEARNING MODEL IMPROVE STUDENTS' DISASTER PREPAREDNESS AND SCIENCE LITERACY? A QUASI-EXPERIMENTAL STUDY

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ABSTRACT

Low science literacy among elementary school students may limit their understanding of disaster risks and preparedness. This study examined differences in disaster preparedness and science literacy before and after instruction using socio-scientific issues discovery learning, discovery learning, and cooperative learning. It also assessed learning gains and the effectiveness of socio-scientific issues discovery learning. A quasi-experimental study involved 252 students aged 10–11 years from elementary schools in Yogyakarta City, Indonesia. Students completed pretests and post-test across three groups. Data were analysed using multivariate statistical procedures. Significant differences were found in disaster preparedness and science literacy among the three learning models. Socio-scientific issues discovery learning produced the highest gains in disaster preparedness ($g = 0.73$, high) and science literacy ($g = 0.82$, high), compared with discovery learning ($g = 0.65$ and 0.63) and cooperative learning ($g = 0.54$ and 0.52). The learning model significantly affected disaster preparedness ($p < 0.001$, partial $\eta^2 = 0.691$) and science literacy ($p = 0.004$, partial $\eta^2 = 0.654$). These findings indicate that integrating socio-scientific issues into discovery-based learning can effectively enhance disaster preparedness and science literacy among elementary school students.

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1. INTRODUCTION

Indonesia is situated within the Pacific Ring of Fire, one of the most tectonically active regions in the world. This geographical condition makes Indonesia highly susceptible to earthquake disasters Yan et al. (2023) stated that earthquakes are vibrations that propagate through the Earth's surface. In general, earthquakes occur when the movement of tectonic plates under pressure releases accumulated energy. Indonesia lies at the junction of three major tectonic plates, namely the Indo-Australian Plate, the Eurasian Plate, and the Pacific Plate. The movement and interaction of these plates frequently trigger seismic activity and earthquakes in various regions of Indonesia (Senkaya et al., 2024).

A large part of Indonesia is situated within subduction zones, where a denser oceanic plate

moves beneath a continental plate. This tectonic process can generate powerful earthquakes that have the potential to cause extensive damage (Dartanto, 2022). In addition, Indonesia's numerous active volcanoes contribute to the country's overall seismic hazard. Active volcanoes in Indonesia also play a role in increasing the risk of earthquakes. This volcanic activity is often triggered by the same plate movements that cause earthquakes (Virtriana et al., 2022). Indonesia has a large population living in earthquake-prone areas, especially in coastal areas and dense urban areas, increasing the potential for human and material losses in the event of an earthquake (Dartanto, 2022).

Indonesia is recognized as a region with a high level of seismic activity. Based on data from various international geological agencies such as the United States Geological Survey (USGS) and BMKG (Meteorology, Climatology, and Geophysics Agency), Indonesia records thousands of earthquakes every year, with some of them having significant magnitudes. According to a report by the (World Health Organization, 2024), Indonesia often falls into the category of countries with the highest earthquake risk globally. The mapping of earthquake-prone areas in Yogyakarta shows that the region includes areas with seismic intensities ranging from V to VI on the Modified Mercalli Intensity (MMI) scale.

Earthquake disasters remain a potential hazard in Yogyakarta and its surrounding areas. This condition is associated with the location of Yogyakarta and its surroundings along an active fault system that is influenced by tectonic plate movements (De & Thamarapani, 2022). Geologically, Yogyakarta and its surrounding areas are located within the propagation zone of seismic waves generated by the reactivation of an ancient fault. This fault is estimated to be approximately two million years old and is located about 10 km east of the Opak Fault with a parallel orientation. The complex geological conditions of the region allow seismic waves from this unnamed ancient fault to propagate toward the Opak Fault system and the Bantul Graben. The seismic waves also extend toward the Dengkeng (Baturagung) Fault system in southern Klaten. This propagation of seismic waves has contributed to severe damage along an area extending from Bantul to Klaten. Faults and fault structures represent zones of weakness in the Earth's crust that are particularly susceptible to earthquake vibrations (Saputra et al., 2020).

Earthquakes are geological disasters that occur as natural phenomena and remain difficult to predict. This phenomenon seems to appear suddenly and irregularly, (Triyanti et al., 2023) explained that the disaster preparedness of the Indonesian people is still weak, this is evidenced by the large number of casualties and property casualties from each disaster event. Limited disaster preparedness can increase the potential impact of disasters. Disaster preparedness represents a strategic stage because it determines the ability of community members to cope with disaster events. In areas characterized by high levels of hazard and vulnerability, strong community preparedness can help reduce the potential impacts of disasters (Labrague & Hammad, 2024). According to the National Board for Disaster Management, (2024) guidelines for the preparation of Disaster Management Plans, education serves as an effective means of developing disaster-related knowledge and awareness. Integrating disaster management concepts into the educational curriculum represents a form of passive mitigation that can be implemented within the community. Furthermore, disaster mitigation through education can also be categorized as a form of active non-structural mitigation.

Disaster preparedness can be provided at multiple levels, at the school and classroom levels. This is the first step in building disaster resilience throughout the community. Students who

have learned about disaster preparedness can become agents who will disseminate disaster preparedness education to their families and communities, thus creating community preparedness in the face of disasters (Stjernholm, 2024). Government efforts to provide knowledge about disasters in schools through intra- and extracurricular activities have not been optimally realized. The realization of the national curriculum in Indonesia, learning tools for disaster education at the primary to tertiary levels has not been socialized evenly (Canlas, 2023). In addition to equipping disaster preparedness, learning also needs to equip science literacy.

Science literacy refers to the knowledge and skills that enable individuals to identify questions, obtain new knowledge, explain scientific phenomena, understand the characteristics of science, and formulate conclusions based on evidence (Fortus et al., 2022). Science literacy skills need to be developed in students in the 21st century so that students can overcome various problems related to science. Indonesia's science literacy ranking is 67th. Indonesia recorded a decline in science literacy scores, from 379 in 2018 to 366 in 2022 (OECD, 2023). The decline in Indonesia's PISA score is thought to be due to the learning lag during the Covid-19 pandemic (Artobatama et al., 2023). In addition, there is a lack of connection between what students learn in class and what they face daily in their lives (Ashley et al., 2023). Chen (2024) explained that science learning in Indonesia is fixated on content that requires students to memorize material, rather than referring to contexts that develop science literacy.

Contextual learning that utilizes the surrounding environment as the primary learning resource can optimize the development of disaster preparedness and science literacy among students. Socio-scientific issues learning provides a context that is relevant to students' lives so that it can train students to face, negotiate, and engage in society to make problem-solving decisions in everyday life situations related to science and technology (Dayan & Tsybulsky, 2024). SSI includes science content knowledge that corresponds to real-life experiences (Aziz & Johari, 2023). SSI learning actively engages students in discussions to address and solve relevant problems (Syifa et al., 2024).

Socio-scientific issues can be integrated with discovery learning. Discovery learning is learning designed so that students are actively involved in analyzing and solving problems to discover new knowledge (Nurdiyanto et al., 2024). The learning environment in discovery learning requires discussion activities in groups to search, process, and solve problems by utilizing various learning resources (Ozdem-Yilmaz & Bilican, 2025). The integration of SSI in discovery learning can be one of the teacher's efforts to improve the science learning process to be more meaningful so that it can improve disaster preparedness and science literacy. In previous research, Kumar et al. (2024) explained that SSI learning can have a positive impact on student learning of science content, argumentation, and reasoning.

Although previous studies have demonstrated the potential of SSI to improve students' science content knowledge, argumentation, reasoning, and engagement with real-world problems, the use of SSI in science learning has not been sufficiently integrated with a systematic discovery learning framework that explicitly connects scientific concepts, authentic disaster-related contexts, and the development of disaster preparedness and science literacy. Existing studies have generally examined SSI as a context for discussion, argumentation, and decision-making, while discovery learning has emphasized students' processes of investigating and constructing knowledge. Consequently, there remains a research gap concerning how these two approaches can be systematically integrated into a learning model that simultaneously develops students' abilities to

investigate scientific problems, construct evidence-based explanations, make decisions related to socio-scientific issues, and prepare for disaster situations. This research gap is particularly relevant to the Indonesian educational context, where students continue to demonstrate relatively low levels of science literacy and science instruction often emphasizes content acquisition and memorization. Therefore, this study aims to develop a Socio-Scientific Issues Discovery learning model that integrates authentic disaster-related socio-scientific issues into the stages of discovery learning.

The novelty of this study lies in the systematic integration of SSI and discovery learning to create a contextual learning experience that connects scientific knowledge with disaster preparedness and the development of science literacy. Specifically, SSID advances beyond prior SSI-based and discovery-learning studies through a distinct pedagogical mechanism: the stages of discovery learning (problem identification, data collection, verification, and generalization) are not applied to neutral scientific content but are driven by an authentic, disaster-related socio-scientific dilemma that requires students to weigh scientific evidence against social, ethical, and community considerations at each stage. Theoretically, this mechanism differs from conventional discovery learning, which structures inquiry around concept discovery without a values-laden dilemma, and from conventional SSI-based instruction, which typically engages students in argumentation and decision-making without explicitly scaffolding student-led scientific investigation; SSID instead couples the two processes so that evidence-based inquiry and socio-scientific decision-making continuously inform one another, which is expected to jointly strengthen students' science literacy and disaster preparedness in ways neither approach achieves alone. The developed model is expected to offer an innovative learning framework that enables students to actively investigate real-world problems, use evidence to construct scientific understanding, engage in argumentation and decision-making, and develop preparedness for disaster-related situations.

Discovery learning has been shown to enhance students' creative thinking and problem-solving abilities (Akihary et al., 2023), as well as their scientific process skills (Daniel et al., 2023). However, studies examining the effectiveness of the Socio-Scientific Issues Discovery learning model in science education, particularly in enhancing disaster preparedness and science literacy, remain limited. Based on these research gaps, this study addresses the following research questions: (i) How do students' pretest and posttest scores in disaster preparedness and science literacy differ among those who participate in the Socio-Scientific Issues Discovery learning model, discovery learning model, and cooperative learning model? (ii) How do the improvements in students' disaster preparedness and science literacy differ among the three learning models? and (iii) How effective is the Socio-Scientific Issues Discovery learning model in improving students' disaster preparedness and science literacy?

Accordingly, this study aims to examine the effectiveness of the Socio-Scientific Issues Discovery learning model in enhancing students' disaster preparedness and science literacy. Specifically, this study compares students' pretest and posttest scores and their improvements in disaster preparedness and science literacy across the Socio-Scientific Issues Discovery learning model, discovery learning model, and cooperative learning model. In addition, this study evaluates the effectiveness of the Socio-Scientific Issues Discovery learning model in improving both disaster preparedness and science literacy.

2. METHOD

The quantitative research design uses the quasi-experimental method. This research does not allow for control of all relevant variables (Cham et al., 2024). This study aims to evaluate the effectiveness of the Socio-Scientific Issues Discovery learning model in improving students' disaster preparedness and science literacy in earthquake-related learning. The study involved one independent variable, namely the learning model, which consisted of three levels: the socio-scientific issues discovery (SSID) learning model, the discovery learning model, and the cooperative learning model. The dependent variables were disaster preparedness and science literacy. This study employed a nonequivalent pretest-posttest control-group design, as proposed by Creswell & Creswell (2021), as presented in Table 1. This design was selected because intact classes were used as the research groups, and the students were administered pretests and posttests before and after the learning intervention.

Table 1. Nonequivalent pretest-post-controlled-group design

Group	Pretest	Treatment	Posttest
Experiment Class	P1	T1 (SSID)	P3
Control Class 1	P2	T2 (Discovery Learning)	P4
Control Class 2	P3	T3 (Cooperative Learning)	P5

The research procedure consisted of several sequential stages, beginning with a needs analysis, followed by validation and practicality evaluation of the SSID learning model, implementation of the learning treatments, and evaluation of students' learning outcomes. First, a needs analysis was conducted through literature studies, interviews, and observations related to student characteristics, science subject matter, and the learning models and methods used in elementary school science learning in Yogyakarta City. The needs analysis aimed to identify problems related to the implementation of science learning and the development of students' disaster preparedness and science literacy.

Second, the SSID learning model and its supporting learning tools were validated by five experts through focus group discussions (FGD). The practicality of the SSID learning model was subsequently evaluated by five elementary school teachers. The validation and practicality evaluations were conducted before the model was implemented in the experimental classes. The five experts were purposively selected based on the following criteria: (1) holding a doctoral degree in science education, elementary education, or a closely related field; (2) having a minimum of five years of relevant academic or professional experience in instructional design, discovery learning, or socio-scientific issues-based learning; and (3) having published research or practical work related to science literacy or disaster education. The panel comprised two science education lecturers, one elementary education lecturer, one instructional media/assessment expert, and one disaster education specialist, each of whom independently reviewed the SSID model and its supporting learning tools before the FGD was conducted to reach consensus on the necessary revisions. Third, before the learning intervention, all research groups were administered a pretest to measure students' initial disaster preparedness and science literacy. The experimental class received the SSID learning model (T1), control class 1 received the discovery learning model (T2), and control class 2 received the cooperative learning model (T3).

In the experimental class, the SSID learning model integrated socio-scientific issues related to disaster contexts into the discovery learning process. Students were engaged with authentic disaster-related issues, identified and formulated problems, collected and analyzed relevant information, investigated the scientific concepts underlying the issues, discussed alternative solutions, constructed evidence-based explanations and arguments, and communicated their conclusions. These activities were designed to connect scientific knowledge with real-life disaster contexts and to develop students' disaster preparedness and science literacy.

In control class 1, students were taught using the discovery learning model, which emphasized the discovery of scientific concepts through problem identification, data collection, data processing, verification, and conclusion drawing. In control class 2, students were taught using the cooperative learning model, which emphasized collaborative group activities, discussion, completion of learning tasks, and presentation of group results. Thus, the three groups received the same science content but differed in the learning model and learning context. Fourth, after the learning intervention, all groups were administered a posttest. The pretest and posttest results were subsequently analyzed to determine differences and improvements in students' disaster preparedness and science literacy and to examine the effectiveness of the SSID learning model compared with the discovery learning and cooperative learning models.

The research was conducted in elementary schools in Yogyakarta City, Yogyakarta Province, Indonesia. The study focused on science learning among sixth-grade elementary school students. Permission to conduct the research was obtained from the principals and teachers of the participating schools. The researcher acted as an observer and assisted in preparing the learning materials, while the teachers implemented the assigned learning models in their respective classes. The participants involved in this study were sixth-grade students from Yogyakarta City elementary schools who came from high-, medium-, and low-category schools. The school category is based on the data from the Assessment of Regional Education Standardization of Yogyakarta City. The participants were selected using cluster random sampling. This technique was chosen because the sampling units consisted of naturally organized classes, making it appropriate for selecting groups of students while maintaining the existing classroom structure (Spies et al., 2023). A total of 252 sixth-grade students participated in this study. The participants were selected from schools classified into high, medium, and low categories. In each school category, one class was assigned to the experimental group, one class to control group 1, and one class to control group 2. Each group comprised 28 students, resulting in a total of nine classes. The distribution of participants across the groups is presented in Table 2.

Table 2. Description of research participants

School Category	Group	Gender		Total	Age range (years)
		Male	Female		
High	Experiment	14	14	28	10-11
	Control 1	16	12	28	10-11
	Control 2	13	15	28	10-11
Medium	Experiment	15	13	28	10-11
	Control 1	14	14	28	10-11
	Control 2	12	16	28	10-11
Low	Experiment	14	14	28	10-11

Control 1	13	15	28	10-11
Control 2	12	16	28	10-11
Total	123	129	252	10-11

The SSID learning model and its supporting learning tools were evaluated for validity and practicality before their implementation in the experimental classes. Five experts in the field of learning model development participated in the expert validation process. The validity of the SSID learning model was evaluated through expert judgment. The experts assessed several components of the model, including its rationale and theoretical foundation, syntax, social system, principles of reaction, support system, instructional effects, and accompanying effects. The results of the expert validation are presented in Table 3.

Five elementary school teachers assessed the practicality of the SSID learning model. The teachers evaluated the extent to which the SSID learning model and its supporting learning tools could be implemented in science instruction. The results of the practicality assessment are presented in Table 4. The assessment used a five-point Likert scale, with scores of 5 for very good, 4 for good, 3 for sufficient, 2 for less, and 1 for very less.

Table 3. Expert Validation Results of the SSID Learning Model

Aspects	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5	Average	Category
Rational theoretical model	1	1	1	1	1	1	Valid
Syntax	1	1	1	1	1	1	Valid
Social system	1	1	1	1	1	1	Valid
Reaction principle	1	1	1	1	1	1	Valid
Support system	1	1	1	1	1	1	Valid
Instructional and accompanying effects	1	1	1	1	1	1	Valid

Table 4. Teacher Evaluation Results of the Practicality of the SSID Learning Model

Aspects	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5	Average	Category
Rational theoretical model	1	1	1	1	1	1	Valid
Syntax	1	1	1	1	1	1	Valid
Social system	1	1	1	1	1	1	Valid
Reaction principle	1	1	1	1	1	1	Valid
Support system	1	1	1	1	1	1	Valid
Instructional and accompanying effects	1	1	1	1	1	1	Valid

The content validity of the SSID learning model and its supporting learning tools was assessed by five experts. The assessment results were analyzed using Aiken's formula according to Equation 1. The disaster preparedness and science literacy instruments were also assessed by

five experts using a four-point rating scale consisting of without revision (4), minor revision (3), major revision (2), and unusable (1). The assessment results were analyzed using Aiken's V coefficient. This study used a significance level of 0.05.

$$V = \frac{\sum s}{[n(c-1)]} ; s = \sum ni (r - l_0) \quad (1)$$

where V is the validity index; $s = r - l_0$; r is the rating assigned by each validator; l_0 is the lowest rating category; n is the number of validators; and c is the number of rating categories.

The SSID learning model was considered valid when the obtained Aiken's V coefficient met the predetermined critical criterion at a significance level of 0.05.

Three types of instruments were used in this study: (1) an assessment sheet for the SSID learning model, (2) a disaster preparedness questionnaire, and (3) a science literacy test. The SSID learning model assessment sheet was used during the expert validation and teacher practicality evaluation. Disaster preparedness was measured using a questionnaire, while science literacy was measured using a multiple-choice test.

The disaster preparedness questionnaire comprised 20 statements, while the science literacy instrument contained 20 multiple-choice questions. The questionnaire measured students' knowledge, attitudes, and behaviors related to disaster preparedness, whereas the multiple-choice test assessed students' science literacy skills. The objective scoring of the multiple-choice test also helped minimize potential rater bias.

Indicators of science literacy skills in the study were adapted from PISA 2022 (OECD, 2023). Disaster preparedness indicators in this study were adapted from Guo et al. (2025), Sonmez & Gokmenoglu (2023), Widowati et al. (2023). The indicators of disaster preparedness used as the basis for developing the disaster preparedness questionnaire are presented in Table 5.

Table 5. Indicators of disaster preparedness

Aspects	Indicators
Knowledge, attitudes and skills	Knowledge of natural disasters in general Causes of occurrence Intensity of disaster Attitudes to reduce the impact of disasters
Emergency response planning	Items that need to be saved during an earthquake Important things to have/do for emergency response planning
Disaster warning	Knowledge of the existence of an earthquake warning system Actions to take when hearing earthquake warning signs
Resource mobilization	Evacuation drills and simulations Dissemination of disaster-related matters

These indicators were used to develop the 20-item disaster preparedness questionnaire used in the study. The indicators of science literacy used as the basis for developing the science literacy test

are presented in Table 6. The indicators were adapted from PISA 2022 (OECD, 2023).

Table 6. Science literacy indicators

Aspects	Indicators
Explaining phenomena scientifically	Recalls and applies existing knowledge appropriate for a given situation Make and give appropriate explanations, predictions Identify, use and model simple drawings to explain scientific phenomena encountered in daily life
Identify scientific problems	Identify problems that might be investigated in a particular scientific study
Interpret data and evidence scientifically	Analysing and interpret data to draw appropriate conclusions

These indicators were used to develop the 20-item multiple-choice science literacy test. After the disaster preparedness and science literacy instruments met the predetermined content validity criteria based on Aiken's V analysis, they were administered to 28 students who were not included in the research sample. The responses were analyzed using the Quest program to examine item fit and reliability based on the Rasch model Koyuncu & Şata (2023) explained that the Quest program can be used to validate variables with dichotomous, polytomous, and combination data. Item fit was determined based on the Infit Mean Square (INFIT MNSQ) value using the Rasch model. An item was considered to fit the model when its INFIT MNSQ value was within the range of 0.77–1.33 (Koyuncu & Şata, 2023). Item acceptance was also examined using the Outfit t statistic. Items with Outfit t values ≤ 2.00 were considered acceptable, whereas items with Outfit t values > 2.00 were considered unacceptable (Tesio et al., 2024). Instrument reliability was assessed based on the reliability of item estimates. A higher reliability value indicates greater consistency of the measurement and provides stronger evidence that the instrument can produce consistent results (Wang & Engelhard, 2026). Validity and reliability ensure that the measuring instrument is effective and reliable in producing accurate data. These validity and reliability analyses were conducted to ensure that the instruments were appropriate for measuring students' disaster preparedness and science literacy before their use in the experimental study.

Table 7. Validity of disaster preparedness and science literacy

Variable	No Item	INFIT MNSQ	OUTFIT T	Description
Disaster Preparedness	Item 1	0.92	0.8	Fit and pass
	Item 2	1.15	1.0	Fit and pass
	Item 3	0.99	0.8	Fit and pass
	Item 4	1.01	0.8	Fit and pass
	Item 5	1.10	1.1	Fit and pass
	Item 6	0.99	0.9	Fit and pass
	Item 7	1.03	1.2	Fit and pass
	Item 8	0.94	1.1	Fit and pass
	Item 9	0.98	1.2	Fit and pass

	Item 10	0.96	0.8	Fit and pass
Science Literacy	Item 1	0.95	0.9	Fit and pass
	Item 2	0.94	0.8	Fit and pass
	Item 3	1.05	1.2	Fit and pass
	Item 4	1.00	0.9	Fit and pass
	Item 5	0.96	0.8	Fit and pass

The analysis indicated that all items in the disaster preparedness questionnaire and science literacy test had INFIT MNSQ values ranging from 0.77 to 1.33, which fell within the acceptable range. Therefore, all items were considered to fit the Rasch model. In addition, all items had Outfit t values ≤ 2.00 and were therefore retained. The reliability of the item estimates was 0.84, indicating consistent measurement results (Wang & Engelhard, 2026). The improvement in students' disaster preparedness and science literacy was analyzed using the normalized gain (N-gain) score based on the pretest and posttest results. The N-gain was calculated using the equation proposed by Deng et al. (2026), as shown in Equation 2.

$$N - gain = \frac{\% posttest score - \% pretest score}{maximum score - \% pretest score} \quad (2)$$

The N-gain scores were interpreted according to the criteria proposed by Hake (1999) as shown in equation 2. The gain score criteria according to Deng et al. (2026), are $g \geq 0.70$ (high), $0.30 \leq g < 0.70$ (medium), and $g < 0.30$ (low). To determine the effectiveness of the SSID learning model in improving disaster preparedness and science literacy, the effect size was examined using partial eta squared (η^2). The magnitude of the effect was interpreted based on the criteria proposed by Sommet et al. (2023).

The differences in students' disaster preparedness and science literacy across the SSID, discovery learning, and cooperative learning groups were examined using multivariate analysis of variance (MANOVA). This analysis aimed to determine whether the learning models produced statistically significant effects on both dependent variables simultaneously. Partial eta squared (η^2) was used to measure the effect size. The improvement in students' performance within and across the learning groups was evaluated using N-gain scores calculated from the pretest and posttest results. The N-gain results were used as descriptive evidence of the magnitude of improvement, whereas MANOVA was used to test the statistical significance of differences among the learning groups.

3. RESULTS AND DISCUSSION

The profile of students' disaster preparedness was analyzed using descriptive statistics based on the pretest and posttest scores. The results of the descriptive analysis are presented in Table 8.

Table 8. Results of Descriptive Analysis of Disaster Preparedness

Indicator Value	Experiment		Control 1		Control 2	
	Beginning	End	Beginning	End	Beginning	End
Maximum	47	100	40	93	47	93
Minimum	7	53	7	47	7	47
Mean	25.44	79.78	24.88	73.56	25.19	72.93

Table 8 presents the disaster preparedness scores of students in the three learning groups. Students in the SSID learning group obtained a maximum pretest score of 47, a minimum score of 7, and a mean score of 25.44. Following the intervention, the students achieved a maximum posttest score of 100, a minimum score of 53, and a mean score of 79.78. Students in control group 1, which implemented the discovery learning model, obtained a maximum pretest score of 40, a minimum score of 7, and a mean score of 24.88. After the intervention, their maximum posttest score reached 93, while the minimum score was 47 and the mean score increased to 73.56. Students in control group 2, which implemented the cooperative learning model, obtained a maximum pretest score of 47, a minimum score of 7, and a mean score of 25.19. Their posttest results showed a maximum score of 93, a minimum score of 47, and a mean score of 72.93.

The descriptive results indicate that students' disaster preparedness improved across all three learning groups. However, the SSID group demonstrated the greatest improvement among the three groups. The researchers further analyzed the pretest and posttest scores using the normalized gain (N-gain) equation to determine the magnitude of the improvement. The N-gain results are presented in Table 9.

Table 9. Test results of gain score disaster preparedness

Class	Gain Score	Category
Experiment	0.73	High
Control 1	0.65	Medium
Control 2	0.54	Medium

Table 9 indicates that students' disaster preparedness improved across all three learning groups. The experimental group achieved an N-gain score of 0.73, which was classified as high. Control group 1 obtained an N-gain score of 0.65, while control group 2 obtained a score of 0.54; both scores were classified as moderate. These findings demonstrate that the SSID group experienced the greatest improvement in disaster preparedness. However, the N-gain scores only indicate the magnitude of improvement and cannot determine whether the differences among the learning groups are statistically significant. Therefore, the researchers conducted further inferential analyses using MANOVA and post hoc comparisons. The profile of students' science literacy was analyzed using descriptive statistics based on the pretest and posttest scores. The results of the descriptive analysis are presented in Table 10.

Table 10. Results of descriptive analysis of science literacy

Indicator Value	Experiment		Control 1		Control 2	
	Beginning	End	Beginning	End	Beginning	End
Maximum	60	100	65	95	60	90
Minimum	15	70	20	50	20	45
Mean	37.81	89.06	38.75	70.93	38.44	70.46

Table 10 presents the science literacy scores of students across the three learning groups. Students in the SSID group obtained a maximum pretest score of 60, a minimum score of 15, and a mean score of 37.81. Following the intervention, their maximum post test score increased to 100, while the minimum score reached 70 and the mean score increased to 89.06. Students in control group 1 obtained a maximum pretest score of 65, a minimum score of 20, and a mean score of 38.75. After the intervention, their maximum post test score reached 95, the minimum score was 50, and the mean score increased to 70.93. Students in control group 2 obtained a maximum pretest score of 60, a minimum score of 20, and a mean score of 38.44. Their post test results showed a maximum score of 90, a minimum score of 45, and a mean score of 70.46.

The descriptive results indicate that science literacy increased in all three learning groups, with the highest posttest mean obtained by the SSID group. The improvement in science literacy was further examined using the normalized gain (N-gain) score. The results are presented in Table 11.

Table 11. Results of the science literacy gain score test

Class	Gain Score	Category
Experiment	0.82	High
Control 1	0.63	Medium
Control 2	0.52	Medium

Table 11 indicates that the experimental group achieved an N-gain score of 0.82, which was classified as high. Control group 1 achieved an N-gain score of 0.63, whereas control group 2 obtained a score of 0.52; both scores were classified as medium. These results indicate that the SSID group demonstrated the greatest improvement in students' science literacy.

To examine whether the three learning models resulted in statistically significant differences in students' disaster preparedness and science literacy, the researchers conducted a multivariate analysis of variance (MANOVA). The analysis involved three learning groups, namely the SSID, discovery learning, and cooperative learning groups. The multivariate test results and the tests of between-subjects effects are presented in Tables 12 and 13, respectively.

Table 12. Multivariate Results of the Effect of Learning Model on Disaster Preparedness and Science Literacy

Learning Model	Sig.	Partial Eta Squared
SSID, Discovery, Cooperative	0.000 < 0.05	0.890

Table 12 indicates that the significance value was below the predetermined significance level of 0.05. This finding demonstrates that the learning model produced a statistically significant

multivariate effect on students' disaster preparedness and science literacy. The partial eta squared value of 0.89 indicates that the learning model had a large effect on the combined dependent variables.

Table 13. Results of Tests of Between-Subjects Effects on Disaster Preparedness and Science Literacy

Learning Model	Dependent Variable	Sig.	Partial Eta Squared
SSID, Discovery, Cooperative	Disaster Preparedness	0.000 < 0.05	0.691
	Science Literacy	0.004 < 0.05	0.654

Table 13 indicates that the learning model had statistically significant effects on disaster preparedness and science literacy when analyzed separately. The partial eta squared value for disaster preparedness was 0.691, indicating a large effect. Similarly, the partial eta squared value for science literacy was 0.654, which also represents a large effect. These findings demonstrate that the learning model made a substantial contribution to the differences observed in both dependent variables.

Because the MANOVA results indicated significant differences among the learning groups, post hoc comparisons using the Bonferroni method were conducted to identify which pairs of learning models differed significantly in their effects on disaster preparedness and science literacy. The results are presented in Table 14.

Table 14. Post hoc test results

Dependent Variable	Sig.
Disaster Preparedness	SSID and Discovery = 0.000 < 0.05
	SSID and Cooperative = 0.000 < 0.05
	Discovery and Cooperative = 1.000 > 0.05
Science Literacy	SSID and Discovery = 0.000 < 0.05
	SSID and Cooperative = 0.000 < 0.05
	Discovery and Cooperative = 1.000 > 0.05

Table 14 indicates that the SSID learning model produced significantly different results in disaster preparedness compared with both the discovery learning model and the cooperative learning model. However, the analysis revealed no significant difference between the discovery learning and cooperative learning models. A similar pattern was observed for science literacy: the SSID learning model differed significantly from both comparison models, whereas no significant difference was found between the discovery learning and cooperative learning models. These results provide statistical evidence that the SSID learning model was more effective than both comparison models in improving disaster preparedness and science literacy.

The higher N-gain scores and the significant differences identified through the MANOVA and Bonferroni post hoc analyses indicate that the SSID learning model was more effective than the discovery learning and cooperative learning models in improving disaster preparedness and science literacy. This difference can be understood from the distinctive learning context provided by SSID. Unlike conventional discovery learning, which primarily emphasizes students' discovery of scientific concepts, and cooperative learning, which emphasizes interaction and collaboration

in completing learning tasks, SSID places scientific concepts within authentic socio-scientific problems that require students to consider scientific evidence together with social, environmental, and ethical perspectives.

This contextualization is particularly relevant for elementary school students because their learning is strengthened when abstract scientific concepts are connected to concrete and meaningful experiences. An earthquake provides an authentic context that students can relate to because the consequences of an earthquake involve not only scientific processes but also decisions about preparedness, prediction, mitigation, community safety, and the limitations of available technology. By confronting students with such a dilemma, SSID requires them to move beyond recalling scientific information and to use that information to understand a problem, compare perspectives, evaluate possible solutions, and make decisions. Real problems presented to students can support knowledge construction and meaningful understanding (Çalik & Wiyarsi, 2025), while presenting real-life problems can also support the development of science literacy (Sjöström, 2025).

The cognitive demands of the earthquake-related socio-scientific dilemma may also explain why SSID produced greater improvement in disaster preparedness. Students are not simply asked to memorize what an earthquake is or what should be done during a disaster. Instead, they are required to consider uncertainty and conflicting claims, such as the expectations of communities for accurate earthquake prediction and the scientific limitations of earthquake prediction technology. This process encourages students to connect scientific knowledge with decisions about mitigation and preparedness. Open-ended questions can stimulate students' thinking in developing disaster preparedness (Al Thobaity, 2024).

In the SSID learning process, students worked in small groups to identify the core issues surrounding earthquake prediction and its consequences for society. They examined arguments concerning earthquake prediction and considered different perspectives, including those of scientists, communities, and government. This activity provided students with an opportunity to recognize that a scientific problem may have different interpretations depending on the available evidence and the interests of different stakeholders. Identifying the problem is an important initial step because students need to understand the nature of the problem before determining appropriate solutions (Huang & Jew, 2026).

For elementary school students, this process can support the gradual development of scientific reasoning because students are guided from a concrete situation the possibility and impact of an earthquake to questions that require them to examine evidence and determine appropriate actions. Rather than receiving a predetermined explanation from the teacher, students construct an understanding of the problem through discussion and investigation. This characteristic distinguishes SSID from discovery learning that is not explicitly framed around a socioscientific dilemma.

Students then searched for and collected information from various sources, including internet-based resources, to address the problems identified. They shared information within their groups and considered the perspectives of scientists, communities, and government. For example, students examined the limitations of earthquake prediction technology from a scientific perspective, community expectations regarding accurate prediction, and the importance of disaster mitigation from a government perspective. Technology can facilitate students' access to information and additional literature (Qureshi et al., 2023), while social interaction provides

opportunities for students to exchange ideas and collaborate in solving problems (Qi & Derakhshan, 2025).

The importance of this activity lies not merely in collecting information but in helping students compare and connect information from different perspectives. In the context of science literacy, students are therefore encouraged to use scientific information to interpret a real problem rather than treating scientific knowledge as isolated content. This process may explain the higher science literacy gains observed in the SSID group.

Students subsequently discussed possible solutions by considering environmental, health, community, scientific, moral, and ethical perspectives. This stage is an important distinguishing feature of SSID because students must negotiate different viewpoints before determining an appropriate solution. The activity does not require students merely to find one correct answer; instead, students are encouraged to justify their decisions based on available evidence and the consequences of alternative solutions.

Such activities may be particularly valuable for elementary school students because guided discussion provides a social context in which students can externalize their thinking, listen to alternative explanations, and reconsider their initial ideas (Aybek & Aybek, 2024). Students who are trained to identify problems and understand problem patterns can become more accustomed to selecting appropriate problem-solving strategies (Yuhana & Fajari, 2025).

Students presented the results of their discussions and formulated conclusions based on the evidence and perspectives they had considered. Presentation and discussion activities provided opportunities for students to communicate their ideas and respond to the ideas of their peers (Gillies, 2023). These activities also encouraged students to listen to and respect different viewpoints (Wade et al., 2023). However, communication skills were not measured as a dependent variable in this study; therefore, these activities are discussed as learning processes that may support the development of science literacy and disaster preparedness rather than as an empirically measured outcome.

Reflection at the end of the learning process further allowed students to reconsider what they had learned, the difficulties they encountered, and the strategies they used to solve the problem (Sørensen et al., 2023). This reflective process is consistent with a constructivist view of learning, in which students actively construct knowledge through experience, observation, analysis, and reflection (Shaby et al., 2024). The teacher therefore functions primarily as a facilitator who guides discussion and negotiation rather than as the sole source of knowledge (Relmasira et al., 2023).

Taken together, the findings suggest that the superiority of SSID was not simply due to the use of group work or discovery activities, because these elements were also present in the comparison models. Rather, the advantage of SSID lies in the integration of discovery learning with a meaningful socioscientific context. The earthquake dilemma required students to connect scientific concepts with real-life consequences, examine competing perspectives, seek evidence, negotiate possible solutions, and reflect on the implications of their decisions. This combination provided a stronger cognitive and contextual demand than discovering scientific concepts alone or working cooperatively to complete learning tasks. Consequently, SSID provided students with repeated opportunities to apply scientific knowledge to an authentic problem, which is consistent with the higher improvement in both disaster preparedness and science literacy observed in this study.

From a practical perspective, teachers implementing SSID need to carefully select socioscientific issues that are appropriate for students' developmental level and closely related to their local context. Teachers should provide sufficient scaffolding so that students can distinguish scientific evidence from opinions, compare different perspectives, and formulate reasonable solutions. The teacher's role is therefore to facilitate the negotiation process and guide students toward evidence-based conclusions while allowing students to remain actively involved in constructing their understanding.

4. CONCLUSION

The results of the data analysis showed significant differences in students' disaster preparedness and science literacy among the socio-scientific issues discovery learning (SSID), discovery learning, and cooperative learning groups. The pretest-post test scores of disaster preparedness and science literacy increased significantly in all three groups, with the SSID learning model showing greater improvement than the discovery learning and cooperative learning models. These findings demonstrate that the SSID learning model is more effective than the two comparison learning models in improving students' disaster preparedness and science literacy. These findings have practical implications for elementary science learning. Teachers can use the SSID learning model as an alternative approach to integrate science concepts with authentic disaster-related issues that students encounter in their daily lives. In implementing the SSID learning model, teachers need to act as facilitators by providing relevant socio-scientific issues, guiding students in identifying and analysing problems, facilitating evidence-based discussion and negotiation, and helping students formulate appropriate solutions. This approach provides students with opportunities to apply scientific knowledge to real-life situations while developing their preparedness to respond to disaster-related problems. At the school level, schools can support the implementation of the SSID learning model by providing contextual learning resources and disaster-related instructional materials. Schools can also facilitate opportunities for students to discuss and investigate issues relevant to their local environment. Thus, the SSID learning model can serve not only as an approach for improving science literacy but also as a practical means of integrating disaster preparedness into elementary science education.

Further research could examine the implementation of the SSID learning model through technology-based learning environments. Digital simulations, interactive multimedia, and other technology-supported learning resources could be integrated into SSID activities to provide students with richer opportunities to investigate disaster-related socio-scientific issues. This recommendation is particularly relevant because the present study primarily used paper-based learning materials. These findings should be interpreted in light of several limitations. First, this study used a quasi-experimental, non-randomized design, so the possibility of pre-existing differences between the SSID, discovery learning, and cooperative learning groups cannot be entirely ruled out despite the use of pretest control and comparable class characteristics. Second, the sample was limited to 252 students aged 10–11 years from elementary schools in Yogyakarta City, Indonesia, a population that may differ in prior disaster exposure, socioeconomic background, and curricular experience from students in other regions. Third, because the earthquake-related socio-scientific issue was selected to reflect the local disaster context of Yogyakarta, the findings may not generalize directly to other disaster types, grade levels, or

cultural and educational settings without further adaptation and testing. Future studies involving randomized designs, more geographically diverse samples, and a wider range of socio-scientific disaster contexts are needed to strengthen the generalizability of these findings.

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