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THE EFFECTS OF SOCIO-SCIENTIFIC INQUIRY BASED LEARNING ON STUDENTS' PROBLEM-SOLVING SKILLS

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Abstract. *Future needs and challenges, especially in complex real-world problem-solving, require education to equip individuals with quality skills. Inquiry-based learning that integrates socio-scientific issues (SSI) can significantly develop students' problem-solving skills. This study aims to test the effects of the Socio-Scientific Real-world Inquiry (SSRI) learning model in improving problem-solving skills. This study used a quasi-experimental pretest-posttest non-equivalent control group design, which involved measuring problem-solving skills before and after the intervention in two groups: the experimental group (44 students) with a socio-scientific real-world inquiry learning model and the control group (46 students) with inquiry learning. Differences in pretest and posttest scores on each aspect of problem-solving skills were analyzed using a paired sample t-test, while an independent sample t-test was used to compare posttest scores between the two groups. Analyze the effect size of each aspect of problem-solving skills in the control group and experimental group using Cohen's Effect Size (ES). The results showed that the SSRI learning model was significantly more effective in improving problem-solving skills than inquiry learning. The findings suggest that SSRI can be an effective learning approach for empowering educators and guiding educational policymakers in fostering essential problem-solving skills for future generations.*

Keywords: *biology education, experimental study, inquiry learning, problem-solving, socio-scientific issues*

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Introduction

In the 21st century, global needs and challenges demand learning that focuses not only on academic achievement but also on the development of various important skills that students must possess. One of the key skills required is problem-solving skills (Bayu et al., 2023; Dilekçi & Karatay, 2023; Kain et al., 2024). Problem-solving skills enable students to identify, analyze, and solve various complex problems effectively. These skills are also a provision for students in dealing with various complex and dynamic situations in everyday life (Sharma et al., 2022; Tang et al., 2023; Zyoud et al., 2022). Learning designed to develop problem-solving skills can make students become adaptive individuals who are able to find solutions to real-world problems (Fahmi et al., 2021; Sukontawaree et al., 2022). Problem-solving oriented learning, such as inquiry, encourages students to actively participate, take initiative and take responsibility for their learning, thus equipping them with the skills needed in the future (Dah et al., 2024; Fadzil, 2017). Students with problem-solving skills will not only be better prepared academically but will also become individuals who are able to contribute positively to society. In addition, problem solving skills help students overcome various challenges and obstacles with a logical and innovative approach (Csapó & Funke, 2017; Özeren, 2023). Students are more familiar with the problem-solving approach when facing unexpected situations and tend to be calm, analytical and able to find the right solution (Csapó & Funke, 2017; Iwuanyanwu, 2020). Thus, education can be one of the media to develop these skills.

Problem-solving skills are important to develop in education, so education should focus more on participatory and inquiry-based learning. A problem-solving-based learning approach helps students to be actively involved, take initiative, and be responsible for their learning process (Akben, 2020; Ince, 2018). In this way, they not only acquire knowledge but are also trained to think independently and critically in finding solutions to existing problems. Students' success in solving problems depends not only on the mastery of concepts but on the establishment of relationships of all information, knowledge and concepts in the problem (Ince, 2018). Problem-solving skills can also increase students' learning motivation because students are

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actively involved in learning and experience first-hand the relevance of the material they learn to the context of everyday life (Argaw et al., 2017). In the context of education, problem-solving skills have the potential to be developed, especially in learning biology because students are required to think scientifically and critically (Hsu et al., 2024; Nikolić & Antonijević, 2024). In recent years, problem-solving has become a core objective in biology learning (Fitria et al., 2024; Gardner & Belland, 2017). Students' understanding of biological problems that arise can increase their interest in studying biology by means of investigation and problem-solving skills (Nikolić & Antonijević, 2024).

Problem-solving skills can only develop well in a teaching environment that recognizes the importance of these skills and is supported by sustainable and well-planned learning conditions. In this context, efforts to develop problem-solving skills can run more effectively because it includes a process that considers the various aspects needed to hone students' abilities optimally (Çalışkan et al., 2010; Fatmawati, 2020; Malam et al., 2018). In biology learning, the essence of problem-solving is seen in the principle that every learning component needs to reflect the steps in the scientific research process. In this process, students are expected to define and identify problems, formulate hypotheses, conduct tests, and verify their findings (Akben, 2020; Gültekin & Altun, 2022; Lieung et al., 2019). Inquiry learning is popularly used in science classes because it emphasizes scientific activities that can develop students to analyze problems to find solutions to complex problems. Some studies show that with inquiry learning, students are actively involved in discovering knowledge through a series of systematic stages, starting from identifying problems, formulating hypotheses, collecting data, analyzing information, and formulating conclusions (Lazonder & Harmsen, 2016; Sam, 2024). Although biology learning in higher education has placed problem-solving as a top priority, it still faces challenges, and the results achieved are not fully optimal. Scientific-based learning, including the inquiry approach, is still not optimal in developing problem-solving skills. The study of the systematic review indicates that although the inquiry approach has the potential to improve educational outcomes, its implementation is often hampered by a lack of instructional support and a less conducive learning environment (Sam, 2024).

The real-world application learning model (level of inquiry) has the potential to enhance problem-solving skills. Inquiry-based learning at the real-world application level encourages students to implement the knowledge they have learned in a new context by finding solutions to authentic problems (Wenning, 2011b, 2011a). Such inquiry learning provides opportunities for students to conduct independent investigations while still receiving direction from the teacher (Wenning, 2011a). Inquiry-level real-world applications face various challenges. The problems used as learning materials need to fully reflect the authentic situation in the field (Prahani et al., 2021). In addition, the dominant role of the teacher in the learning process can hinder the development of students' independent inquiry and problem-solving skills. The relatively long learning duration can also reduce the interest and enthusiasm of students in participating in the learning (Gormally et al., 2016; Khalaf & Zin, 2018).

One of the main causes is the presentation of problems that need to be more suitable for students' level of understanding, making it difficult for them to process information and develop effective solutions. A study showed that students tend to be more motivated and serious about learning when they are given the opportunity to explore interesting topics and contribute to the achievement of learning objectives (Cents-Boonstra et al., 2021). The problems raised are often irrelevant to the context that is familiar to students, making them experience obstacles in identifying the necessary solution steps. As a result, even though problem-solving has become a focus, some students still struggle to maximize their analytical and critical skills in the process of learning biology. Therefore, adjustments in the presentation of problems to make them more relevant and appropriate to students' capacities are essential to enhance science based learning outcomes and optimize the development of problem-solving skills (Magaji, 2021). Complex, contextual, and contentious issues can be problems that students can be exposed to in their learning. These problems encourage students to enhance critical thinking, analytical skills, and the ability to evaluate different perspectives. Students become interested in exploring controversial issues, analyzing evidence, considering various arguments, and finding appropriate solutions based on deep thinking (Abrami et al., 2015; Byford et al., 2009; Goodenough et al., 2023; Wansink et al., 2023). Complex issues that can be used as interesting learning materials for students are socio-scientific (Ikhwan et al., 2017; Sadler et al., 2016).

SSI are issues that trigger controversy in society because socio-political perspectives influence them. These issues involve social aspects as well as scientific involvement. SSI are very interesting because they are controversial issues that trigger debate in the community, so that they can develop decision making skills in students (Eastwood et al., 2012; Zeidler et al., 2019). SSI is controversial because there are different perspectives, values, and interests of various parties related to a science issue. For example, the issue of genetic engineering raises pros

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and cons between the benefits of technology and ethical and safety considerations (Saad et al., 2017; Subiantoro et al., 2021). SSI used as an issue in learning can be an innovative approach because it integrates real-world problems and raises critical thinking, thus equipping students with skills in dealing with complex problems in society through a series of scientific activities (Kumar et al., 2024; Subiantoro et al., 2021; Viehmann et al., 2024).

The implementation of SSI in science learning in Indonesia is still limited and needs to be improved (Genisa et al., 2020). Although many previous studies have shown that inquiry-based approaches can help improve problem-solving skills, most have not explored the specific role of SSI in inquiry-based learning. In fact, integrating SSI has the potential to add a rich and relevant contextual dimension for students, increase their engagement in learning, and train them to deal with complex real-life problems. In addition, the inquiry approach applied in the classroom is often general. It does not emphasize direct application in real-life contexts, which is important in preparing students for global challenges. Therefore, more specific research is needed to assess the effects of learning models that combine inquiry with real socio-scientific issues in improving problem-solving skills.

Socio-scientific Real-world Inquiry (SSRI) is a learning model that has been developed by integrating real world application-level inquiry learning with SSI-based learning to improve problem-solving skills. Studies show that the use of SSI in inquiry learning enhances students' ability to understand and interact with complex and dynamic contemporary science issues, thus preparing them to face real-world challenges (Gutierez, 2015; Suwono et al., 2023). A study by Qamariyah, et al (2021) revealed that the application of inquiry learning with the context of SSI to students can enhance problem-solving and higher order thinking skills better than traditional teaching methods. Findings from other studies show that learning with SSI fosters critical thinking, open-mindedness, and confidence in reasoning for prospective science teachers (Gul & Akcay, 2020). These studies indicate that this approach not only enriches analytical and critical thinking skills but also equips students with skills to face complex challenges with a scientific and ethical approach.

The development and implementation of the SSRI learning model are needed as an effort to enhance the skills of science teachers. Inquiry learning with socio-scientific issues prepares a person in the future to face complex problems in real life. Through the development of these skills, students are prepared to become active, informed, and committed citizens in solving multidimensional problems. This approach also emphasizes the integration of moral, ethical, and social dimensions in science learning, enabling students to understand and assess the impact of their choices and actions on society. For example, by examining socio-scientific issues, students can develop a global perspective and an awareness of the importance of responsible local action (Amos & Levinson, 2019). In addition, this approach has also been shown to increase students' knowledge of the long-term impact of individual and collective choices on the well-being of society and the environment (Zeidler et al., 2019).

This research presents an innovative learning model called Socio-Scientific Real-world Inquiry (SSRI), a new breakthrough in biology education that develops students' problem-solving skills through a contextual approach that has not been widely used. Although there is extensive information about inquiry learning in biology learning, further studies are needed on the level of effectiveness of inquiry learning with SSI in the context of Genetically Modified Organisms (GMOs) to improve problem-solving skills. This research addresses the limited application of contextualized socio-scientific inquiry in biology education, particularly in the context of GMOs, despite its potential to significantly enhance students' problem-solving skills. The main problem lies in the need for more empirical evidence regarding the effects of Socio-Scientific Real-world Inquiry (SSRI) compared to inquiry learning models in addressing real-world problems.

In answering these challenges, research with appropriate methods and accurate control is needed. This study aims to compare the effects of Socio-Scientific Real-World Inquiry (SSRI) and inquiry-based learning models in enhancing students' problem-solving skills in the context of socio-scientific issues. In addition, this study provides a more detailed analysis through measuring the effect size on each aspect of problem-solving skills, thus strengthening the empirical evidence regarding the effects of SSRI over problem solving skills. This research is important because problem-solving skills are essential for students to navigate socio-scientific issues in real-world contexts. Yet, current approaches, such as inquiry learning, may only partially meet these demands. This research contributes to the pedagogical references by providing a foundation for the development of more effective SSI-based learning models. The findings also encourage educators and policymakers to consider the SSRI learning as an innovation in enhancing problem-solving skills in biology education. Based on this research, important questions were raised, namely: How did the effect of the SSRI learning model on problem-solving skills compare to inquiry learning in socio-scientific issues?

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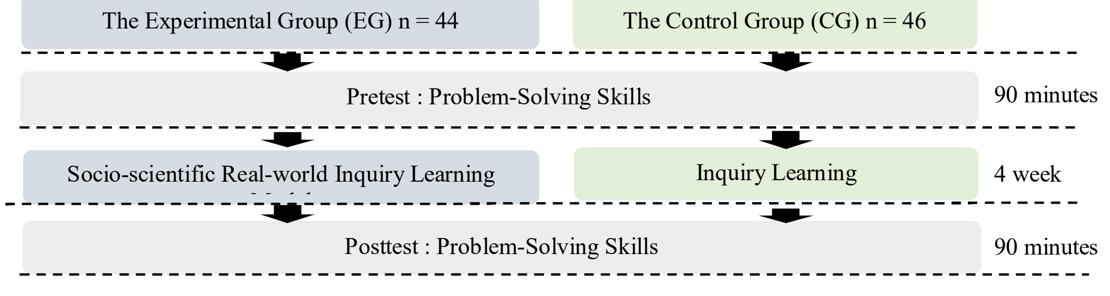
Research Methodology

General Background

This type of study was quasi-experimental, using a pretest posttest non-equivalent control group design, which involves pre- and post-intervention measurements on two groups, one receiving the treatment and one as a control (Figure 1) (Creswell & Creswell, 2018). The procedure of this research includes: first, giving a pretest of problem-solving skills to the experimental and control groups; second, implementing the SSRI learning model to the experimental group (EG), and the inquiry learning model to the control group (CG); third, giving a posttest of problem-solving skills to both groups. The effect of the SSRI learning model was assessed by analyzing and comparing the pretest and posttest scores of each aspect of problem-solving skills between the control and experimental groups. The research was conducted for 4 weeks in the biology education class, at Muhammadiyah University of Surakarta, Indonesia, in November-December 2023. The material used in this study is socio-scientific issues about transgenic products (GMOs).

Figure 1.
Procedure of Experiment



Population and Sample

The population of this research was 119 biology education students of class 2021 at Muhammadiyah University of Surakarta, a private university located in Central Java, Indonesia. The sample was selected by purposive sampling, with relevant criteria focusing on selecting students who had previously completed basic courses and showed interest in socio-scientific issues. These criteria are in line with the purpose of this study, which is to evaluate the effects of the SSRI learning model in improving problem-solving skills in the context of socio-scientific issues related to GMOs. The purposive sampling method was used because researchers could select samples selectively according to the characteristics of the phenomenon in the study so that significant information was obtained about this study. The selected samples were 44 biology education students (experimental group) and 46 biology education students (control group). The sample size of the study was determined according to the number of subjects who met the inclusion criteria. These criteria included students' willingness to participate, their ability to engage in the intervention, and ensuring a balanced group size to facilitate comparative analysis. The Experimental Group (EG) used the SSRI learning model, while the Control Group (CG), as a comparison of experimental results, used an inquiry learning model. The selected research participants have been able and willing to participate in this study with the confidentiality of their identity.

The participants of this study had demographic conditions, namely biology education students in the class of 2021. Their average age ranges from 18-20 years. The gender distribution in the experimental group consisted of 5 males and 39 females, while in the control group, there were 6 males and 40 females. The students shared similar socio-cultural backgrounds, as they predominantly came from the Central Java province, Indonesia. Thus, the participants in this study have relatively the same characteristics, namely student age, grade level, and socio-cultural background. The research participants amounted to 90 students divided into two groups, namely the control group (46 students) and the experimental group (44 students). Students in the experimental group and control group were randomly selected based on the similarity of demographic conditions.

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Procedures

Experimental groups

The Experimental group receiving SSRI learning model treatment, which has the advantage of containing socio-scientific issues as the main problem presented in learning as a stimulus for students to practice the problem-solving based learning. The SSI in this experimental group was GMO crops, which involved scientific, social and ethical aspects. This allowed students to explore various perspectives through discussion activities. The selection of experimental classes in research is an important step that requires careful consideration. The selection considers the characteristics of the participants in accordance with the research objectives. The same characteristics between the EG and CG provide confidence that the results obtained from this study are the result of the intervention carried out (Balkin & Lenz, 2021; Reichardt, 2019). Thus, research bias can be reduced, and the internal validity of the research can be increased.

The SSRI learning model used in this experimental group was an integration of a real-world application model (Wenning, 2011b) with SSI-based learning (Sadler, 2011). The components of the SSRI model consist of (1) a learning syntax consisting of 5 phases; (2) social systems; (3) reaction principles; (4) support systems; and (5) instructional impacts (Joyce et al., 2015). The phases and sub-phases in the SSRI learning model are systematically organized frameworks that guide students in solving scientific and social problems, starting from the problem orientation stage to the reflection stage. Phases serve as the main steps in learning that aim to achieve the expected results, while sub-phases are more detailed steps within each phase that support students in undergoing a structured learning process. The following were phases and sub-phases of the SSRI learning model (Table 1).

Table 1
Phases dan Sub Phases of SSRI Learning Model

a.

Phases	Sub-Phases	Learning Activity
Problem orientation	a. Identification b. Main Topic Formulation	a.1. The provision of SSI developing in the community is associated with learning materials, both texts/readings and other formats. a.2. Students identify socio-scientific issues contained in texts or readings. b. Students determine the core issue by exploring pro and con arguments in the context of SSI.
Manipulation	a. Exploration b. Data Interpretation	a. Students express their views on the main topic which includes pro and con arguments in SSI. b. Students provide explanations supported by scientific evidence to strengthen their arguments.
Generalization	Explanation/ Experimentation	a. Students elaborate on the SSI problem topic theoretically to support their arguments. The theory is explained in a structured way to prove the correctness of students' opinions on the topic of SSI problems.
Verification	a. Discussion b. Communication	a. Students discuss in class or in groups to discuss opinions supported by data, scientific explanations, and personal experiences. This discussion aims to produce appropriate conclusions based on the results of the discussion. These conclusions can be in the form of alternative solutions as an effort to solve the main problems in the SSI topic. b. Students convey the discussion's results in the form of conclusions or alternative solutions in front of the class through oral presentations, posters, or other scientific papers.
Reflection	Reflection	Students evaluate the strengths and weaknesses of the conclusions or alternative solutions proposed and consider the implications that may arise if the solution is applied to a different situation.

The SSRI learning model has the advantage of containing socio-scientific issues as the main problem presented in learning as a stimulus for students to practice problem-solving. The unstructured and controversial nature of SSI can be used to help to improve the quality of problem-solving (Kumar et al., 2024). Students who are faced with controversial socio-scientific issues will engage in dialog, discussion, and debate so that they require thinking skills such as reasoning or evaluation of ethical issues and are able to make decisions about solutions to these problems (Evagorou et al., 2020). Meaningful learning by integrating socio-scientific issues is different from conventional learning and can be challenging.

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Control Groups

The control group in this study was selected carefully to guarantee the validity of the quasi-experimental research. The selected control group considered the similarity of characteristics with the experimental group, including demographics, background, age, and other variables relevant to the study (Miller et al., 2020). The control group was treated with inquiry learning, which is usually applied by lecturers in biology lectures in the classroom. The inquiry learning model is a learning approach that is applied without incorporating SSI into the learning process. Instead, it utilizes general contextual problems that are not directly related to social or controversial issues. For example, contextual problems used in this model include topics such as GMO crops, which emphasize technical and scientific aspects without involving broader social, ethical or controversial dimensions. The inquiry learning used includes the steps of observation, manipulation, generalization, verification, and conclusion based on the results of the investigation and testing. Conclusions can be applied to different situations. The conclusion is then applied to a different situation (Wenning, 2011b). The main intervention difference between the two groups is the implementation of the learning model. The integration of SSI in the real-world application-level inquiry is the specialty of the experimental group, while the control group only applies inquiry learning without any additional innovation. The learning steps of the inquiry learning model in the control group can be seen in full in Table 2.

Table 2
Learning Steps and Learning Activity of Inquiry Learning Model

Steps	Learning Activity
Problem orientation	a. Observe a phenomenon or issue that interests students. b. Students explore and identify the phenomenon or issue and find analogies and other examples related to the phenomenon. c. Students formulate a viable inquiry question.
Manipulation	a. Students discuss in groups the ideas that arise to investigate the phenomenon or issue and formulate an approach to analyze it. b. Students design an investigation plan and carry it out to collect data.
Generalization	a. Students elaborate principles or theories related to the phenomenon or issue they are studying. b. Students formulate a logical and easy-to-understand explanation of the phenomenon or issue.
Verification	Students formulate predictions and test them using general theories or principles that have been developed in the previous stage.
Application	a. Students make their own conclusions and present them in front of other students. b. Conclusions are shared and applied to different situations.

Data Collection Instrument

The instrument used to evaluate problem-solving skills consisted of 8 questions. These questions were carefully designed to measure students' skills to analyze, evaluate, and solve problems in the socio-scientific context of GMOs. The measurement of students' problem-solving skills includes aspects of skills adapted from OECD (2013) that have been adapted to the material of transgenic biotechnology. The aspects and indicators used can be seen in Table 3.

Table 3
Aspects and Indicators of Problem-Solving Skills

Aspect	Description	Indicator
Define the problem	Make linkages and problem relationships from various problems that have been identified from the SSI.	Identify the problems that exist in the discourse presentation about the use of herbicides on soybean crops.
	Determine the main issue/ problem in the SSI that needs to be solved.	Determine the main problem from the problems that occur in the discourse presentation about the use of herbicides on soybean crops.

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Aspect	Description	Indicator
Explore the problem	Formulate problems based on the main issues that have been determined.	Formulate a problem based on the main problem that has been determined in the discourse presentation about the use of herbicides on soybean plants.
	Determine alternative solutions that can be used to solve the main problem.	Determine alternative solutions with a modern biotechnology approach that can be used to solve problems in the discourse presentation on the use of herbicides on soybean plants.
Plan and implement the solution	Create a working design from the alternative solutions chosen to solve the problem.	Determine the tools and materials as well as the function of their use to carry out solutions with a modern biotechnology approach to the discourse presentation on the use of herbicides on soybean plants.
	Implement the solution based on the plan that has been developed.	Create a chart/scheme of solution implementation with a modern biotechnology approach to solve problems in the discourse presentation on the use of herbicides on soybean crops.
Check and reflection	Detect events that may occur beyond the primary outcome as a result of applying the solution.	Describe other impacts that arise as a result of applying solutions with a modern biotechnology approach to solve problems in the discourse presentation on the use of herbicides on soybean crops.
	Reflect on the strengths and weaknesses of the problem-solving process (chosen solution).	Describe the strengths and weaknesses of the solution with a modern biotechnology approach that has been determined to solve the problem in the discourse presentation on the use of herbicides on soybean crops.

The instrument that has been designed is then validated, which includes content and construct validation. The content validity test showed that all question items obtained an Aiken score (V) above .76, so all question items were valid. To test construct validity, the questions were tested on students who had taken biotechnology material. The construct validity test using Rasch model analysis obtained a Cronbach alpha value of .76, which indicates that the instrument is reliable. The instrument was also analyzed from the value of variance explained by measures, which obtained a score of 39.1%. Eigenvalue is quite good because it does not exceed the threshold of 3 (Mokshein et al., 2019). At the same time, the unexplained variance, in contrast, obtained a value range of 7.80% - 13.10%. This value indicates that the instrument is good and able to measure problem-solving skills (Fisher, 2007; Garg et al., 2021; Howells et al., 2020). Before the learning began, students worked on the pretest questions of problem-solving skills for 90 minutes. After the learning is complete, students also answer the problem-solving skills posttest questions for 90 minutes.

Data Analysis

Data from the problem-solving skills test were analyzed by comparing the average scores of the pretest and posttest. Previously, the test data was analyzed to determine the distribution (normality) of the data using the Shapiro-Wilk test. The Shapiro-Wilk test on the pretest and posttest scores of problem-solving skills in CG and EG obtained a $p > .05$, which indicates that the data has a normal distribution. The pretest and posttest scores in CG and EG were also analyzed for homogeneity of variance using the Levene test. The results of the Levene test obtained a $p > .05$, which indicates homogeneous data. Thus, the analysis of differences in problem-solving skills scores in CG and EG uses parametric statistical tests.

Furthermore, a paired sample *t*-test was conducted to determine the difference in the average scores of pretests and posttests for each aspect of problem-solving skills in CG and EG. An Independent sample *t*-test was conducted to determine the difference in the average score of the posttest and between CG and EG for each aspect of problem-solving skills. The magnitude of the influence on each aspect of problem-solving skills in CG and EG was analyzed using Cohen's Effect Size (ES). The Cohen's d value obtained is then categorized with the provisions of the value ≥ 1 (very large); .80 (large); .50 (moderate); .20 (small) (Cohen, 1988).

Research Results

The SSRI learning model was implemented in EG, while the inquiry learning model was implemented in CG in biology learning. Before the learning begins, students are given pretest questions, and at the end of the learning process, they are given posttest questions. The pretest score illustrates the level of students' problem-solving skills before the intervention. In contrast, the posttest score provides insight into the level of problem-solving skills after

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the SSRI learning model is implemented. The descriptive statistics of the pretest and posttest scores of problem-solving skills are presented in Table 4.

Table 4
Descriptive Statistics of The Pretest and Posttest

Aspect	Group	*n*	*M*		*SD*		Minimum		Maximum	
			Pretest	Posttest	Pretest	Posttest	Pretest	Posttest	Pretest	Posttest
Define the problem	CG	46	61.41	7.10	12.86	14.66	50	37.50	87.50	100
	EG	44	61.36	79.83	14.22	13.80	25	50	87.50	100
Explore the problem	CG	46	57.88	69.02	12.46	12.84	37.50	50	75	100
	EG	44	62.50	77.56	15.25	13.09	37.50	50	87.50	100
Plan and implement the solution	CG	46	64.40	69.84	18.44	9.71	25	50	87.50	87.50
	EG	44	62.50	77.56	12.93	10.29	50	50	87.50	100
Check and reflection	CG	46	60.87	67.93	9.72	11.07	50	50	75	87.50
	EG	44	56.25	74.72	9.53	13.61	37.50	50	75	100
Overall Mean	CG	46	61.14	69.97	10.16	8.63	43.75	53.13	81.25	90.63
	EG	44	60.65	77.41	8.64	8.91	43.75	59.38	78.13	93.75

Table 4 shows that overall, the mean posttest was higher than the pretest in CG and EG. The result also occurs in the results of each aspect of problem-solving skills; namely, the posttest average is higher than the pre-test in CG and EG. However, when comparing the overall average pretest and posttest scores between CG and EG, the average in EG is higher than CG. These results can be attributed to the different interventions implemented in CG and EG. In CG, the intervention focused on inquiry-based learning without integrating SSI. In contrast, in EG, the intervention utilized the SSRI model, which emphasizes contextual problem-solving with social, ethical, and scientific dimensions. These different approaches led to differences in the improvement of problem-solving skills, which resulted in higher mean scores in EG compared to CG. Furthermore, the mean pretest and posttest scores were analyzed using a paired sample *t*-test to determine the difference in the mean of each aspect of problem-solving skills in CG and EG (Table 5).

Table 5
Comparison of Improvement in Problem-Solving Skills

Aspect	Group	*n*	Paired Sample t-test		**Effect Size (ES)** *(Cohen's d)*	
			t-value	*p*-value	Point Estimate	Interpretation
Define the problem	CG	46	-4.67	< .0001	.69	Moderate
	EG	44	-6,47	.001	.97	Very large
Explore the problem	CG	46	-4.58	< .0001	.68	Moderate
	EG	44	-5.89	.001	.89	Large
Plan and implement the solution	CG	46	-1.56	.126	.23	Small
	EG	44	-6.59	.001	.99	Very Large
Check and reflection	CG	46	-3.52	.001	.52	Moderate
	EG	44	-7.52	.001	1.13	Very large
Overall Mean	CG	46	-4.53	.001	.67	Moderate
	EG	44	-10.06	.001	1.52	Very large

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The paired sample *t*-test results (Table 5) show that the pretest-posttest scores in each aspect of problem-solving skills in CG and EG have significant differences ($p < .05$), except for the aspect of the plan and implementing the solution in CG, which is not significant ($p > .05$). In the ES value, it is known that in EG, three aspects get the very large category, and one aspect gets the large category, while in CG, three aspects get the moderate category, and one aspect gets the small category. Overall, the ES in EG was greater than that in CG. These results indicate that the SSRI learning model intervention in EG has a greater positive effect on problem-solving skills than the inquiry learning intervention in CG. Furthermore, the average posttest score was analyzed using an independent sample *t*-test to determine the significance of the difference between EG and CG (Table 6).

Table 6
Independent t-test of Problem-Solving Skills

Aspect	Group	*n*	Independent Sample *t*-test (*Sig.*)		Effect Size (ES) *(Cohen's d)*	
			t-value	*p*-value	Point Estimate	Interpretation
Define the problem	CG	46	-2.240	.028	.47	Moderate
	EG	44				
Explore the problem	CG	46	-3.122	.002	.66	Moderate
	EG	44				
Plan and implement the solution	CG	46	-3.661	.001	.77	Large
	EG	44				
Check and reflection	CG	46	-2.598	.011	.55	Moderate
	EG	44				
Overall Mean	CG	46	-4.149	.001	.88	Large
	EG	44				

Table 6 shows that there are significant differences ($p < .05$) in posttest scores between EG and CG in each aspect of problem-solving skills. These results indicate that the SSRI learning model intervention in EG is better than that in CG in improving problem-solving skills. On the ES value, it is known that two aspects obtained the large category, and three aspects obtained the moderate category. The SSRI learning model gives students the ability to identify problems in SSI and plan alternative solutions so they can be trained to implement these solutions.

Discussion

The results indicated a significant difference between the pretest and posttest scores of overall problem-solving skills in CG and EG (Table 5). When viewed from each aspect of problem-solving skills, three aspects are significantly different in CG and EG, while there is one aspect in CG that is not significantly different. The effect of the intervention on CG and EG made a difference in the results. When viewed from each aspect of problem-solving skills, three aspects are significantly different in CG and EG, while there is one aspect in CG that is not significantly different. The effect size in EG is also better than that of CG (Table 5). This finding indicates that the implementation of the SSRI learning model significantly improved problem-solving skills in EG. Further analysis of the mean posttest score of problem-solving skills between CG and EG showed significant differences overall and in each aspect of problem-solving skills (Table 6). The effect size results also show that the intervention in EG has a positive influence on students' problem-solving skills (Table 6). This finding highlights that the SSRI learning model has significant potential in enhancing problem-solving skills. The inquiry learning model integrated with SSI positively impacts problem-solving skills compared to inquiry learning that is not integrated with SSI.

Previous research on biology learning with SSI explains in its findings that it has great potential to improve various student skills, including problem-solving (Istiana & Herawatia, 2019; Owens et al., 2019; Suryani et al., 2020). Students engaging in socio-scientific issues promotes students' understanding of issues relevant to the main problem, helps students use this scientific knowledge in a broader social context and think about the interaction between science and social factors that can influence students' position on complex issues (Kapici & Ilhan, 2014;

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Ke et al., 2021). The integration of SSI in inquiry learning trains students to answer complex questions or solve real-world problems (Högström et al., 2024). Inquiry in biology learning, which is equipped with the use of socio-scientific issues to be criticized and resolved, supports students to be more critical in learning (Suwono et al., 2023) and provides useful and challenging experiences (Rauch & Radmann, 2020). Science teachers who design inquiry learning with socio-scientific issues report success in engaging students, especially when students ask questions about relevant issues that increase active awareness of socio-scientific issues that need to be resolved (Evagorou et al., 2020). These results are consistent with the findings of this study, which revealed that the SSRI learning model effectively improved problem-solving skills in SSI. This model provides significant opportunities for students to participate in in-depth problem-solving and decision-making processes.

The results of this study found that the SSRI learning model was effective in improving problem-solving skills in biology learning (Table 5, 6). The learning stages in the SSRI learning model were developed specifically to train students to solve problems in the context of SSI. The integration of SSI in inquiry has an important role in improving problem-solving skills. SSI in inquiry learning stimulates students to argue, debate, and think critically, which places students in the SSI position. The situation raises students' critical ideas in responding to SSI and solving the main problems in SSI. Thus, SSRI learning has a better positive effect on problem-solving skills in the context of SSI than inquiry learning, which is not integrated with SSI. SSI, which has a debatable, contemporary, contextual nature, provides an interesting and challenging learning nuance for students in training them to solve problems.

Various research results corroborate that inquiry learning with SSI can train and develop students' skills to solve complex problems. Inquiry is important in science learning and needs to be trained to students before they become teachers. The trend of applying inquiry in science education is shown in a literature review which states in its findings that currently, there is a need for a lot of study on the epistemic aspects of inquiry in science education (Dah et al., 2024; Dimopoulou & Gasparatou, 2024; Strat et al., 2024). Recent studies on inquiry applied in science learning provide evidence that it positively impacts the enhancement of students' problem-solving skills. Collaborative inquiry implemented in online classrooms contributes to problem-solving skills in both high and low-performing groups (Bunterm et al., 2012; Song et al., 2022). However, the findings suggest collaborative inquiry still needs pedagogical development (Song et al., 2022).

The integration of SSI in inquiry learning at the real-world application level is needed as a strengthening intervention so that students are stimulated and motivated to understand problems and analyze complex problems to find solutions to complex SSI. SSI in the SSRI learning model, becomes the main point of inquiry learning modification as an effort to optimize problem-solving skills. SSRI learning steps include problem orientation, manipulation, generalization, verification, and reflection. In this socio-scientific real-world inquiry (SSRI) learning model, SSI becomes the main point of inquiry learning modification to optimize problem-solving skills. The SSRI learning steps begin with the presentation of SSI in transgenic biotechnology, which is currently being debated in the community. Socio-scientific issues as problems presented in biology learning can stimulate higher thinking and trigger the desire to solve problems (Nugroho et al., 2023; Presley et al., 2013). The issue of transgenic biotechnology is an interesting socio-scientific issue for the community to be brought into the classroom and become a learning topic (Arslan & Durak, 2024; Dawson & Venville, 2013; Genisa et al., 2020; Nida et al., 2020).

At the problem orientation stage, SSI is presented in the form of discourse and learning media support in the form of videos about GMOs biotechnology (Genetically Modified Organisms/ GMOs). Students listen and identify the SSI and take the main issue in the SSI about GMOs. Students are trained to be more critical in identifying contemporary socio-scientific issues that students may experience themselves. SSI encourages students to systematically identify the components of a problem, including scientific, social, economic, and ethical aspects. Students learn to break down complex problems into simpler components for in-depth analysis (Borgerding & Dagistan, 2018; Namdar & Karahan, 2024). At the manipulation stage, students give their opinions on the main issues in GMOs and begin to engage in the pros or cons of the issue. Students look for strong evidence from various sources and explain to support their opinion on the main issue. The evidence strengthens the student's position on the pros or cons of the main issue of GMOs. This activity facilitates students to explore the problem/issue by finding relevant evidence. The third learning step is generalization; students strengthen their understanding of the theory/content related to SSI to support their opinions. The theory/content material is explained systematically to prove that their opinion about GMOs is correct. Strong evidence and theoretical support become the basis for students to develop appropriate solution steps to the problem of GMOs issues. Students become trained in planning and implementing alternative solutions to solve problems on GMOs topics.

The verification stage contains group and class discussion activities about alternative solutions that have been agreed upon. Alternative solutions are presented as a form of solving the main issues in GMOs. The process

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of discussion and presentation, accompanied by debate, can help students obtain relevant information (Bossér & Lindahl, 2020; Faize et al., 2018). Learning with SSI positively impacts students' skills in debating with other students. In the reflection stage, students evaluate the strengths and weaknesses of the solution to the GMO problem and the implications of the solution when applied to different situations. Reflection activities contribute to awareness of how students learn and solve problems (Li & Lajoie, 2022).

SSI-based inquiry learning provides full opportunities for students to analyze controversial science issues in society critically. When students are faced with complex social-science issues/problems such as biotechnology, they are required to use various perspectives such as science, social, economic, and ethics in analyzing the problem (Viehmann et al., 2024; Yerdelen et al., 2018). Complex thinking will be formed through this process. Teachers who practice SSI-based learning involve students in scientific practices to train them in observing, identifying and concluding a problem (Alcaraz-Dominguez & Barajas, 2024; Fadzil, 2017). In scientific practice, students are asked to explore relevant sources by utilizing various scientific data, research articles, and other scientific sources. These activities are important to understand SSI and be proficient in analyzing problems in controversial issues (Owens et al., 2021). In addition, students are also involved in asking relevant research questions during their scientific activities. Students learn to formulate specific, provable/testable, and meaningful questions on socio-scientific issues. Students' ability to formulate appropriate research questions is important in scientific activities (Herman et al., 2020). The inquiry activities in the SSRI learning model also play a role in training students to collect and analyze data to find alternative solutions to the problem under study. Students practice using scientific methods to collect and analyze relevant data (Dah et al., 2024; Eymur & Çetin, 2024). Data analysis activities in the context of SSI involve technical interpretation of data and consider the social and ethical aspects of the findings. Students practice relating empirical evidence to the wider contextual environment and drawing data-driven conclusions. These skills are important to equip students to deal with complex real-world problems that often require a multi-dimensional problem-solving approach (Eastwood et al., 2012).

The SSRI learning model encourages students to engage in inquiry with SSI as a complex issue that needs to be solved. Raising issues relevant to everyday life, such as climate change, public health, or technological ethics, makes students more engaged and motivated. They learn theory and how to apply the knowledge in a real context, making learning more meaningful and applicable. Inquiry activities and attention-grabbing SSI presentations encourage students to think critically and analytically. Students evaluate multiple sources of information, identify strong evidence, and consider different views. Group discussion activities in SSRI learning are important for training communication and collaboration skills to share opinions and experiences and find solutions. In decision-making to determine solutions, students are taught to analyze relevant data and information and consider the impact of each decision made. Through reflection activities on the process and results of problem-solving, students can develop skills that will be very useful in the real world.

The SSRI learning model was developed specifically to enhance problem-solving skills in the SSI context, so the learning activities are structured to develop each aspect of problem-solving skills, namely: (1) Controversial SSI context: SSI is important to provide meaningful learning situations for students so that they can connect their scientific knowledge with social aspects in the classroom so that they are interested and motivated in finding the meaning of what they learn. The presentation of SSI about GMOs is controversial in society, which makes students interested in learning about it. Students analyze the issue of GMOs and look for relevant solutions to overcome the problem of the world's adversaries with GMOs. (2) Scientific activity: The series of learning activities in SSRI learning facilitates students to identify SSI, determine the main problems in SSI, plan solutions, and verify solutions to reflect on the advantages and disadvantages of solutions in solving complex SSI problems. (3) Active learning in problem-solving: The SSRI learning model fully involves students analyzing SSI, finding the main problem, and planning to test solutions in solving problems relevant to everyday life, such as the GMO controversy. Students practice problem-solving by discussing with other students, searching for relevant literature sources, conducting experiments, and communicating the results to others. Thus, SSRI learning creates an interactive and collaborative environment in the classroom. (4) Collaboration, SSRI learning activities encourage students to work in groups, share ideas and perspectives, and integrate various disciplines to formulate comprehensive solutions. With discussion, debate, and joint research activities, students learn to understand other people's points of view, practice communicating and working well together. These activities indicate that SSRI learning helps students understand SSI and improves collaborative and communication skills in dealing with real and complex problems in society.

The SSRI learning model encourages students to understand scientific concepts deeply and train their skills to analyze and solve problems in the context of social and scientific issues compared to traditional learning, which only focuses on assignments. The SSRI approach allows students to engage directly with real situations that require

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critical thinking and problem-solving so that they learn theory and how to apply it in everyday life. Supporting research shows that this approach can improve students' ability to understand scientific concepts, think critically, and solve problems (Owens et al., 2021). The role of lecturers in learning is to facilitate and guide students to practice solving complex problems. Lecturers not only deliver information but also as mentors who encourage students to develop critical and analytical thinking skills to solve problems. By creating an interactive learning environment, lecturers help students analyze problems, explore various alternative solutions, and consider the social impact of their decisions (Afzal et al., 2023; Kinskey & Newton, 2024; Viehmann et al., 2024). Thus, students are more flexible when collaborating with others. Students work in teams to exchange ideas and opinions and even debate in solving problems (Mao et al., 2024; Rosen et al., 2020).

Although the SSRI learning model has many advantages, this approach also has limitations. One of the areas for improvement is that this learning is still limited to GMO-related topics. This topic limitation reduces the variety of learning contexts that attract students from various interest backgrounds. Therefore, in future research, exploring the use of SSI in other vital areas such as health, environment, and energy is recommended. This broader approach will allow students to examine and consider scientific issues relevant to their daily lives, thus enriching their understanding and increasing their attraction to science learning. Another limitation of this study is that the results may have limited generalizability due to the SSRI learning model applied in a specific context. The diversity of students' backgrounds, including culture, the education system in schools or colleges, and geographical location, may affect the effectiveness of learning models in various contexts. This study also used two classes within one college, so there might be different results if the SSRI learning model is applied in a broader scope. In addition, involving students with diverse demographic backgrounds in the classroom may provide a more thorough insight into the effectiveness of SSRI learning models. External factors such as family conditions and socioeconomic status may also influence students in developing problem-solving skills. Despite the limitations, the results and findings of this study are expected to provide knowledge and insight into the potential of the SSRI learning model in problem-solving skills in the context of SSI.

Finally, the implementation of the SSRI learning model has been proven to significantly improve students' problem-solving skills. Research comparing the experimental group using the SSRI learning model and the control group applying inquiry learning convinces that integrating SSI in inquiry learning is better in promoting problem-solving skills. This reinforces previous research, although some studies have also reported that inquiry positively impacts problem-solving activities. In addition, integrating SSI in inquiry-based learning related to real-world situations provides a significant motivational boost for students. The often controversial nature of SSI topics arouses students' curiosity and interest in exploring critical issues from different perspectives. This approach encourages them to actively seek additional information, evaluate the accuracy and relevance of data, and develop strong arguments to solve the problems. Thus, the approach not only stimulates interest in learning but also prepares students to contribute as individuals ready to face and solve real-life problems.

Conclusions and Implications

Through detailed data analysis and interpretation, this study provides strong empirical evidence that the SSRI learning model is more effective in enhancing problem-solving skills than inquiry learning. When viewed separately between the experimental and control groups, both groups experienced increased problem-solving skills. Real-world application-level inquiry learning integrated with SSI contributes positively to students' problem-solving skills compared to inquiry learning, which does not emphasize SSI in its learning. The effect of this integration is evident from the improvement of students' skills to identify problems, propose alternative solutions, and implement these solutions effectively in a socio-scientific context. This shows that in biology learning, there needs to be innovation in inquiry learning to equip students with various essential skills to face complex future problems.

The implication of the results of this study is that the integration of real world application level inquiry learning model with the SSI approach can be an effective innovation in learning biology to enhance students' problem solving skills. With real-world context in inquiry learning, students not only gain theoretical understanding but also relevant practical skills in dealing with complex problems. The application of SSRI that emphasizes social and scientific contexts has the potential to develop critical thinking, analysis, and synthesis ability in students, which are indispensable in overcoming various global challenges. Therefore, educators and educational policymakers need to consider the integration of this method in the curriculum as one of the strategies to equip students with skills that are more adaptive and responsive to the dynamics of social life in the future.

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Declaration of Interest

The authors declare no competing interest.

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Appendix

1. Problem Solving Skills Instrument Framework

Instrument Type : Written Test
Instrument Form : Essay Questions
Number of Items : 8 Questions

Indicators	Indicators for the Questions	Question Number
Aspect: Define the problem		
Make a problem sketch (connection) from various problems that have been identified.	Students are able to identify issues in the SSI discourse presentation on the use of herbicides on soybean plants, based on scientific and non-scientific perspectives (e.g., economic, ethical, or social)	1
Determine the main problems that need to be resolved	Students are able to determine the main problem in the SSI discourse presentation on the use of herbicides on soybean plants, based on scientific and non-scientific perspectives (for example, economic, ethical, or social)	2
Aspect: Explore the problem		
Create a problem formulation based on the main problem that has been determined	Students are able to formulate problems based on the main problems that have been determined in the SSI discourse presentation on the use of herbicides on soybean plants.	3
Determine alternative solutions that can be used to solve the main problem.	Students are able to determine alternative solutions with a modern biotechnology approach that can be used to solve problems in the SSI discourse presentation on the use of herbicides on soybean plants.	4
Aspect: Plan and implement the solution		
Create a work plan/design from the alternative solutions chosen to solve the problem.	Students are able to determine the tools and materials and their functions for use in implementing solutions using a modern biotechnology approach in the SSI discourse presentation on the use of herbicides on soybean plants.	5
Implement solutions based on the plans that have been prepared	Students are able to create a chart/scheme for implementing solutions using a modern biotechnology approach to solve problems in the SSI discourse presentation on the use of herbicides on soybean plants.	6
Aspect: Check and reflection		
Detecting events that may occur outside the primary outcome as a result of implementing the solution.	Students are able to describe other impacts that arise as a result of implementing solutions with a modern biotechnology approach to solving problems in the SSI discourse presentation on the use of herbicides on soybean plants.	7
Reflecting on the advantages and disadvantages of the problem-solving process (chosen solution).	Students are able to describe the advantages and disadvantages of solutions using a modern biotechnology approach that has been determined to solve problems in the SSI discourse presentation on the use of herbicides on soybean plants.	8

2. Problem Solving Skills Questions

Instructions:

a) Fill in your identity on the answer sheet correctly before working on the questions. Identity includes a) Full name, b) Study Program, c) Institution, d) Gender, e) Origin (from village/city).
b) Read each question carefully.
c) Work on the answer sheet provided.
d) The number of questions is 8 essays with a maximum completion time of 90 minutes.
e) Read the following text carefully to answer questions 1-8.

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Use of Glyphosate Herbicide on Soybean Crops

Soybean plants (Glycine max L. Merill) in Indonesia are food crop commodities with high economic value (Supadi, 2009). Soybean seeds contain essential amino acids that are higher than poultry meat (Tando & Juradi, 2019). Potential soybean crops are an opportunity for farmers in Indonesia to grow soybeans. One of the problems experienced by Indonesian farmers when planting soybeans is weed interference, which affects soybean production. Weeds harm soybean plants through competition for one or more growth factors, including nutrients, water, and light. Weeds that grow can be reduced manually by weeding each plant. This effort is certainly not an effective and efficient one because it requires a lot of time and labor. The need for labor for weed control, which is quite large, can be reduced by using herbicides (Situmorang 2011). The results of research by Suyamto & Wahyu (2015) show that the use of herbicides effectively suppresses weed growth.

Indonesian farmers still rely on herbicides containing glyphosate to control weeds. Glyphosate is a herbicide that has non-selective and systemic properties that can control most perennial weeds. Glyphosate is also very effective in controlling grass weeds as a post-emergent herbicide (Oktavia & Evizal, 2014). The continuous use of herbicides, especially those containing glyphosate, will certainly cause problems such as weed resistance to herbicides and a decrease in the quality and quantity of nutrients in the soil. Another problem arises: the nature of glyphosate also has an impact on soybean plants themselves, namely abnormal soybean growth characterized by yellowing leaves. In addition, glyphosate can affect pigments until chlorotic growth stops, and growth can die (Moenandir, 2010). Overcoming this requires innovative solutions with a biological approach so that soybean plants can grow and produce soybean seeds optimally.

Answer the following questions on the answer sheet provided with clear answers.

1. Based on the reading, what problems occur when using herbicides to control weeds in soybean plants based on scientific and non-scientific perspectives (for example, economic, ethical, or social)?
2. After you know the problems in using herbicides on soybean plants, what are the main problems of using herbicides on soybean plants based on the reading based on scientific and non-scientific perspectives (for example, economic, ethical, or social)?
3. Make a problem formulation based on the main problem (answer number 2).
4. As a student who has studied biotechnology, write a project title/ topic about the right solution to solve the main problem, taking into account scientific aspects and community needs.
5. Based on the solution you have determined, create a design for it (it can be a scheme/ chart/ description point).
6. Create a scheme/ chart/ descriptive points for implementing the solution you have determined by utilizing the necessary biological tools.
7. Suppose the solution you have determined was implemented in real terms. What would be the positive and negative impacts/implications for soybean plants or the environment in general based on scientific and non-scientific perspectives (e.g., economic, ethical, or social)?
8. In your opinion, what are the advantages and disadvantages of your solution if it is implemented specifically on soybean plants themselves?

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3. Problem Solving Skills Assessment Rubric

Aspect	Indicator	Score			
		4	3	2	1
Define the problem	Making a problem sketch (connection) of various socio-scientific issues that have been identified	The results of the problem identification are written in great detail, specifically, and systematically, based on scientific and non-scientific perspectives (for example, economic, ethical, or social).	The results of the problem identification are written in detail and specifically, but less systematically, based on scientific and non-scientific perspectives (e.g., economic, ethical, or social).	The results of the problem identification are written in less detail and specificity, and less systematically, based on scientific or non-scientific perspectives (for example, economic, ethical, or social).	The results of the problem identification are written in a non-detailed, non-specific and non-systematic manner.
	Determine the main problems that need to be resolved	The main issues identified are important and are written logically and systematically, based on scientific and non-scientific perspectives (e.g., economic, ethical, or social).	The identified issues are important and written logically but less systematically, based on scientific and non-scientific perspectives (e.g., economic, ethical, or social)	The issues identified are important and are written less logically and less systematically, based on scientific or non-scientific perspectives (e.g., economic, ethical, or social).	The main problem determined is less important, illogical, and unsystematic, based on scientific and non-scientific perspectives (e.g., economic, ethical, or social)
Explore the problem	Create a problem formulation based on the main problem that has been determined	The problem formulation is very logical, systematic, and uses relevant question sentences according to the main problem.	The problem formulation is quite logical and relevant, but less systematic, and uses relevant question sentences according to the main problem.	The problem formulation is less logical and less systematic and uses relevant question sentences according to the main problem.	The problem formulation is not logical, not systematic, or not relevant.
	Determine alternative solutions that can be used to solve the main problem.	Alternative solutions are written logically, relevantly and systematically, to solve the identified problem, taking into account scientific aspects (modern biotechnology approaches) and community needs.	Alternative solutions are written logically, relevantly but less systematically, to solve the identified problem, taking into account scientific aspects (modern biotechnology approaches) and community needs.	Alternative solutions are written in a less logical, less relevant and less systematic way, to solve the main problem that is determined, by considering scientific aspects (modern biotechnology approaches) or community needs.	Alternative solutions are written illogically, irrelevantly and unsystematically.
Plan and implement the solution	Create a work plan/design from the alternative solutions chosen to solve the problem.	The design is written very systematically, including tools, materials and work steps that are applicable to solving the main problem that has been determined.	applicable tools, materials and work steps to solve the specified problem	The design is written less systematically and less fully (tools, materials and work steps) that are applicable to solve the specified problem	The design is written in an unsystematic manner and is not applicable to solving the identified problem.
	Implement solutions based on the plans that have been prepared	The solution is implemented in real or theoretical terms, logically and systematically by reviewing the literature in accordance with the specified solution design.	The solution is implemented in a real or theoretical way logically but less systematically by reviewing the literature according to the specified solution design.	The solution is implemented in a real or theoretical way but is less logical and less systematic by reviewing the literature in accordance with the specified solution design.	The solution is implemented in a real or theoretical way but is not logical and not systematic by reviewing the literature.

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Aspect	Indicator	Score			
		4	3	2	1
Check and reflection	Detecting events that may occur outside the primary outcome as a result of implementing the solution.	Write down other impacts (positive and negative) in great detail, systematically, and in accordance with literature reviews based on scientific and non-scientific perspectives (e.g., economic, ethical, or social)	Write down other impacts (positive and negative) in sufficient detail, systematically, and in accordance with literature reviews, based on scientific and non-scientific perspectives (for example, economic, ethical, or social)	Writing other impacts (positive and negative) but less detailed, less systematic, and in accordance with literature reviews, based on scientific or non-scientific perspectives (for example, economic, ethical, or social)	Write down other impacts (positive and negative) but not in detail, not systematically.
	socioscientific problems (chosen solutions).	Writing the advantages and disadvantages very completely, in detail and systematically, from the initial process of identifying the problem to implementing the solution.	Write down the advantages and disadvantages in a complete, detailed and systematic manner, from the initial process of identifying the problem to implementing the solution.	Writing only the advantages or disadvantages, not detailed enough and not systematic enough, from the initial process of identifying the problem to implementing the solution.	Just write the advantages or disadvantages, not in detail and not systematically.

4. Scoring

$$\text{Value} = \frac{\text{Total score obtained} \times 100}{32}$$

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