The Effect of Integrating Socio-Scientific Issues into Problem-Based Learning on Students' Problem-Solving Skills in the Topic of Work and Energy

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Abstract - *This study aims to examine the effect of integrating Socio-Scientific Issues (SSI) into the Problem-Based Learning (PBL) model on students' problem-solving skills in the topic of work and energy. A quasi-experimental method with a non-equivalent control group design was employed. The sample consisted of two tenth-grade classes at SMAN 6 Malang, selected through cluster sampling. Class X-4 served as the experimental group, which received the PBL-SSI model, while class X-3 served as the control group, which received the standard PBL model. The research instrument was a five-item essay test developed based on problem-solving indicators. The instrument underwent rigorous validation, including content and empirical validity assessments, reliability testing, item discrimination analysis, and difficulty level analysis, to ensure its suitability as a measurement tool. Data were analyzed using prerequisite tests, an independent-samples t-test, N-Gain analysis, and effect size calculation. The pretest t-test results indicated no statistically significant difference in initial abilities between the two groups (sig. = 0.161 > 0.05), whereas the posttest results revealed a statistically significant difference (sig. = 0.000 < 0.05). The experimental group achieved an average N-Gain of 0.77 (high category), compared with 0.62 (medium category) for the control group, with an effect size of 1.3, indicating a large effect. The most notable improvements in the experimental group were observed in the problem comprehension and solution planning indicators. Contextual problems based on SSI encouraged students to connect physics concepts with real-world phenomena, while discussion, exploration, and reflection activities helped them develop systematic problem-solving strategies and evaluate solutions based on scientific evidence. These findings suggest that the PBL-SSI model is more effective than the standard PBL model in enhancing students' problem-solving skills in the context of work and energy.*

Keywords: *Problem-Based Learning; Problem Solving; Socio Scientific Issue*

INTRODUCTION

Problem-solving skills is an essential component of both academic development and social life, particularly within the evolving landscape of 21st-century education (Budiyono et al., 2024). In the realm of physics, this skill requires a structured approach, ranging from problem identification, hypothesis formulation, and data collection and processing, to drawing appropriate, evidence-based conclusions (Zhu et al., 2023). Consequently, learning physics goes beyond merely recalling facts or memorizing formulas; it encompasses the development of analytical skills, creative reasoning, and a systematic mindset (Wider & Wider, 2023).

As a fundamental science that empirically examines natural phenomena, physics is constructed through a series of scientific processes involving facts, concepts, principles, laws, postulates, and theories (Trianiza et al., 2022). Physics education aims to actively involve students in scientific activities that enable them to explore and understand natural phenomena. Through this process, students are expected to develop conceptual knowledge, strengthen scientific skills, and cultivate attitudes that contribute to the attainment of learning objectives (Vioni et al., 2025). However, physics often presents a distinct challenge for students, particularly regarding the topics of work and energy, which are

known to be complex and difficult to grasp. This directly affects learning outcomes, as indicated by an average misconception rate of 36% across these topics, encompassing the sub-units of energy, work, the law of conservation of mechanical energy, and the relationship between work and energy (Mufti & Sunarti, 2024).

Various factors contribute to the difficulty of learning physics, including the abstract nature of concepts, the complexity of mathematical formulas, and the limited connection between concepts and real-life situations (Khatri et al., 2017). Research by Dinata (2024) also indicates that when solving problems related to work and energy, students tend to be more capable of describing the problem than resolving it through in-depth computational analysis. Such difficulties ultimately result in low motivation and learning interest, which indirectly hinders the development of problem-solving skills (Vuztasari & Diyana, 2024).

Educators play a strategic role in selecting appropriate learning models and strategies aligned with competency standards, thereby creating a learning environment that is conducive, interactive, and innovative. An approach that emphasizes the connection between work and energy concepts and everyday phenomena is essential for making the material more contextual and easier to understand (Amsikan, 2022; Ramli et al., 2024). One alternative learning model with significant potential to meet these needs is Problem Based Learning (PBL), This model starts by giving students a real-life situation or problem to help them build their ability to think critically and solve problems. (Salsabila & Muqowin, 2024).

Studies show that using the PBL approach helps students develop better problem-solving skills. It does this by having students look closely at problems and break them down, whether they work alone or with others. Research by Dewi (2024) shows that the PBL model effectively boosts student learning enthusiasm, fostering active engagement and resulting in an average material comprehension rate of 93.2%, while also cultivating a spirit of collaboration among students. Furthermore, a study by Dinda R & Atmojo (2024) It was found that students who learned using the PBL model showed much bigger improvements in their problem-solving skills than students who followed traditional teaching methods. PBL has been proven to enhance problem-solving skills and deepen students' understanding of specific physics topics, evidenced by higher average final scores and score dispersion, and is considered particularly effective for less motivated students, as it encourages consistent study and work throughout the semester, thereby boosting motivation to learn physics (Marcinauskas et al., 2024).

The Problem Based Learning (PBL) model lets students practice thinking through problems and improves their ability to analyze ideas related to work and energy. To make PBL more connected to real-life social problems, the model can be combined with the Socio Scientific Issues (SSI) approach, which is a teaching method that connects scientific ideas to different social and environmental issues in society (Permanasari et al., 2021). Incorporating SSI through controversial issues that spark debate is particularly well-suited for science education. The issues selected should encourage students to participate in meaningful discussions and debates. These activities are closely associated with the development of argumentation skills, which constitute an essential foundation for fostering critical thinking. Furthermore, the issues raised typically lack a single, definitive answer; instead, they offer diverse

alternative solutions, thereby accustoming students to thinking like problem solvers. Since the learning process is grounded in scientific literacy, it also directly fosters a sense of moral responsibility. This moral responsibility serves as a crucial foundation for realizing Education for Sustainable Development (ESD) (Permanasari et al., 2021). By integrating PBL with SSI, students not only gain a theoretical understanding of physics concepts but also enhance their ability to apply these concepts to analyze and address real-world problems encountered in daily life.

Several previous studies also support the effectiveness of combining PBL and SSI. Research by Hestiana & Rosana (2020) demonstrated that the implementation of PBL-SSI effectively improved junior high school students' scientific literacy and problem-solving skills. Furthermore, a study by Azizah et al. (2021) found that the implementation of student worksheets (LKS) organized according to SSI-based PBL stages enhanced students' scientific literacy by encouraging active student participation in the learning process and deepening their understanding of the connections between scientific concepts and real-world issues. Research by Fadly et al. (2022) also confirmed that SSI can enhance literacy skills and hone critical thinking, problem-solving, and scientific communication skills, particularly when supported by learning tools specifically designed to foster these competencies. Thus, this strategy helps students improve their problem-solving skills, especially regarding the topic of work and energy.

Most research on combining PBL and SSI remains within the general scope of science education, with few studies specifically examining its application to physics instruction regarding work and energy. Addressing this gap, the present study aims to examine the impact of integrating PBL and SSI on students' problem-solving skills in work and energy, particularly through physics phenomena that are relevant to everyday life. The findings are anticipated to provide empirical evidence to support the development of physics learning models centered on problem-solving and socio scientific issues.

RESEARCH METHODS

This study employs a quantitative approach using a quasi-experimental method. The quantitative approach aims to examine the effect of the PBL-SSI model on students' problem-solving skills regarding the topic of work and energy. A quasi-experimental design was adopted because the study was conducted with naturally formed classes, precluding the random assignment of subjects. Specifically, a non-equivalent control group design was used; both the experimental and control groups were administered a pretest (Q1 and Q3) prior to the intervention (X1 and X2) and a posttest (Q2 and Q4) following the completion of the intervention, as outlined in Table 1 (Creswell & Clark, 2018). The study was conducted at a public senior high school in Malang City, specifically SMAN 6 Malang, during the even semester of the 2025/2026 academic year.

Table 1. Nonequivalent Control Group Design

Class	Pretest	Treatment	Posttest
Experimental	Q_1	X_1 (PBL-SSI)	Q_2
control	Q_3	X_2 (PBL)	Q_4

Cluster sampling was employed to select the sample, ensuring that every class group had an equal chance of being included in the study. Class X-4 was designated as the experimental group and Class X-3 as the control group, with each class consisting of 30 students. The independent variable in this study was the PBL-SSI model, whereas

students' problem-solving skills were treated as the dependent variable.

Data analysis was conducted through several statistical stages. First, the Shapiro-Wilk normality test was employed to assess whether the data distribution was normal, with a significance value (sig.) > 0.05 serving as the criterion for normality. Second, Levene's test for homogeneity was applied to examine the equality of variances between the experimental and control groups; a significance value (sig.) ≥ 0.05 indicated that the data were homogeneous. Differences in the initial abilities of the two groups were assessed using pretest scores; if the data were normally distributed and homogeneous, an independent sample t-test was performed, whereas if these assumptions were not met, a non-parametric test was used as an alternative. Hypothesis testing was carried out to determine whether a significant difference in problem-solving skills existed between the two groups, with the null hypothesis (H_0) rejected if the significance value (sig.) was < 0.05. Furthermore, the improvement in problem-solving skills was analyzed using the normalized gain (N-gain), based on pretest and posttest scores. The N-gain was calculated by comparing the actual score improvement against the maximum possible score improvement, following the scoring criteria presented in Table 2. As a subsequent step, an effect size analysis was performed using Cohen's d coefficient to measure the magnitude of the treatment's effect on problem-solving skills. The categories for effect size based on Cohen's d are provided in Table 3.

Table *2.* N-Gain Categorization

N-gain Score	Category
$g \geq 0.70$	High
$0.30 \leq g < 0.70$	Medium
$g < 0.30$	Low

Table *3.* Cohen's effect size categorization

Rentang Cohen's	Kategori
$d < 0{,}20$	Negligible
$0{,}20 \leq d < 0{,}50$	Small
$0{,}50 \leq d < 0{,}80$	Medium
$d \geq 0{,}80$	Large

Based on the content validity test results for the problem-solving skills test, as evaluated by two expert validators, an average percentage of 84% was obtained, which falls into the "very high" category. Besides that, based on an empirical validity test using the Pearson Product Moment correlation, the instrument consisting of five items, demonstrated a sufficient level of validity for use in the research. All items yielded corrected item-total correlation coefficients (r-calculated) that exceeded the critical r-table value (0.339), confirming their validity. Specifically, the r-calculated values for items 1 through 5 were 0.420, 0.602, 0.562, 0.432, and 0.487, respectively. These findings confirm that each item effectively measures the intended construct. Regarding difficulty level, all five questions fall into the moderate category, while the discrimination index analysis indicates that every item is effective in distinguishing between students with high and low ability levels. The reliability analysis yielded a Cronbach's Alpha coefficient of 0.729 (considered high) which indicates that the instrument possesses adequate internal consistency. Based on these results, the instrument was considered suitable for measuring students' problem-solving skills in this study.

RESULTS AND DISCUSSION

Results

Descriptive statistics presented in Tables 4 and 5 indicate that the average scores on the pretest were 29.40 for the experimental group and 29.60 for the control group. This similarity in scores indicates that

the initial proficiency levels of both classes were comparable prior to the intervention. This is further supported by the minimum and maximum pretest scores for both classes, which showed no significant differences, thereby confirming that the initial conditions of the two groups were equivalent. Following the intervention, an increase in the mean problem-solving skills scores was observed in both classes.

Table 4. Statistic Descriptive Pretest results

Description	Pretest	
	Control	Experimental
Number of Students	30	30
Minimum Score	20	22
Maximum Score	38	38
Mean Score	29,60	29,40
Standard Deviation	5,103	4,523
Variance	26,041	20,455

Table 5. Statistic Descriptive Posttest results

Description	Posttest	
	Control	Experimental
Number of Students	30	30
Minimum Score	54	72
Maximum Score	88	96
Mean Score	73,60	84,20
Standard Deviation	9,073	6,754
Variance	82,317	45,614

Table 6. Normality Result

Group	N	Statistik Shapiro-Wilk	Sig. (p-value)	Description
Pretest control group	30	0,960	0,302	Normal
Posttest control group	30	0,955	0,230	Normal
Pretest experimental group	30	0,958	0,277	Normal
Posttest experimental group	30	0,957	0,264	Normal

The outcomes of the Shapiro Wilk normality test shown in Table 6 demonstrate significance values of 0.302 for the pretest of the control group and 0.230 for its posttest. In contrast, the experimental group produced significance values of 0.277 for the pretest and 0.264 for the posttest. All significance values exceeded the 0.05 threshold, indicating that the data from all four measurement groups were normally distributed.

Additionally, Levene's test assessing homogeneity yielded significance values of 0.517 for the initial test and 0.092 for the final test. Since both values exceeded the 0.05 significance threshold, the variances of the control group and the experimental group were regarded as similar for the data collected in both the pretest and posttest sessions. The fulfillment of normality and homogeneity assumptions ensures the validity of the comparison between the two groups, meaning any observed differences can be attributed to the applied treatment rather than to pre-existing differences in data characteristics. Consequently, an independent samples t-test was conducted for hypothesis testing. The evaluation of the pretest results yielded a Sig. (2-tailed) value of 0.161, exceeding the 0.05 threshold for significance. As a result, the null hypothesis (H_0) was upheld while the alternative hypothesis (H_1) was dismissed, suggesting that no statistically meaningful variation existed in the students' starting capabilities across the two groups.

Consequently, a t-test for independent samples was executed on the scores from the post-test to assess if there was a notable difference between the control group, instructed via the PBL model, and the experimental group, which was taught using the PBL-SSI model after the intervention. The results from the t-test revealed a significance (2-tailed) value of $p < 0.001$, which is beneath the 0.05 significance level. As a result, the null hypothesis (H_0) was dismissed, and the alternative hypothesis (H_1) was accepted, indicating a statistically meaningful disparity in the problem-solving

skills of students in the control group (PBL) compared to those in the experimental group (PBL-SSI). Following the significant t-test results, a follow-up analysis using effect size was performed. The calculated effect size was d = 1.3, indicating that the impact of the PBL-SSI model fell into the "large effect" category.

To see how significant the difference is, an N-gain calculation is used.

Tabel 7. N-Gain Score Result

N	N-gain Score							
	Control Group				Experimental Group			
	Min.	Max.	Mean	Description	Min.	Max.	Mean	Description
30	0,38	0,83	0,62	Medium	0,61	0,94	0,77	High

Based on the N-gain results presented in Table 7, the value obtained for the control group, which utilized the PBL learning model was 0.62, falling into the medium category. Meanwhile, the N-gain value for the experimental group, which employed the PBL-SSI model, was 0.77, falling into the high category.

The N-Gain analysis, conducted based on problem-solving skills indicators, follows these stages: 1) understanding the problem; 2) planning the solution; 3) executing the solution plan; and 4) reviewing the obtained solution (Pangestu *et al*., 2021). The N-Gain results for each problem-solving indicator are presented in Figure 1.

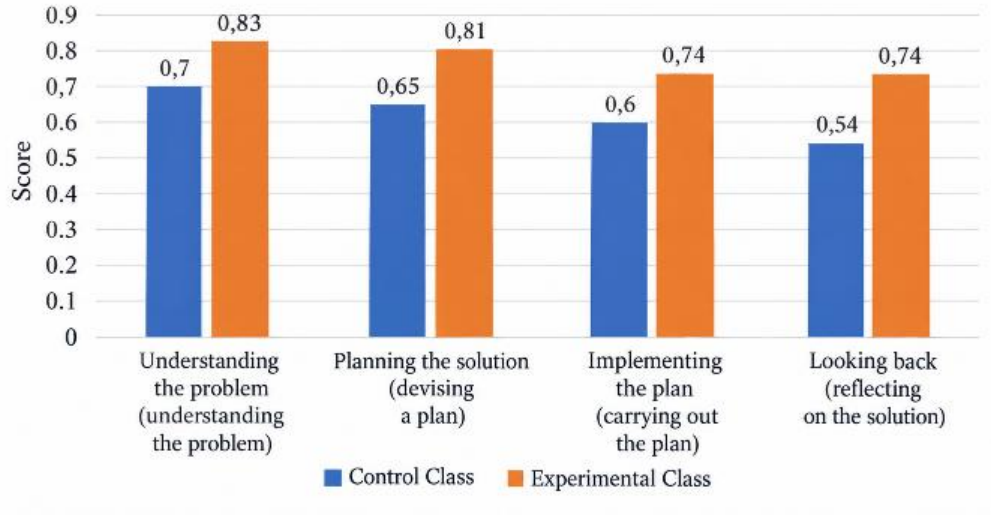

Figure 1. N-Gain results for each problem-solving indicator

Discussion

When evaluated against the Minimum Mastery Criterion (KKM) of 75, the average posttest score of the experimental group exceeded the threshold, whereas the control group remained below it. Although both groups demonstrated an improvement in problem-solving skills compared to their pretest scores, the gain in the experimental group, which utilized the PBL-SSI model was greater than that of the control group, which employed standard PBL. These findings align with research byDinda R dan Atmojo (2024) as well as Dewi et al. (2024), which indicate that PBL can enhance students' problem-solving skills, active engagement, conceptual understanding, and collaboration. Furthermore, Azizah *et al.* (2021) found that PBL-SSI, supported by student worksheets (LKPD), fosters student engagement and helps learners connect academic concepts to real-world issues. Fadly *et al.* (2022) also demonstrated that instruction based on Socio-Scientific Issues

(SSI) has the potential to improve scientific literacy while developing critical thinking, problem-solving, and scientific communication skills. Consequently, the results of this study suggest that the PBL-SSI group achieved higher levels of problem-solving proficiency and greater improvement in these skills compared to the PBL group; however, this difference cannot be attributed solely to the SSI component, given that the study design utilized pre-existing groups and the intervention incorporated multiple instructional elements.

Based on the t-test analysis of the pretest scores, a sig. (2-tailed) value of $p = 0.161$ (> 0.05) was obtained. This indicates that the null hypothesis (H0) is accepted and the alternative hypothesis (H1) is rejected, demonstrating no significant difference in the students' initial abilities between the two class groups. Subsequently, a t-test was conducted on the posttest scores to assess whether any disparity existed between the control group—which utilized the Problem-Based Learning (PBL) model, and the experimental group—which employed the PBL-SSI (PBL integrated with Socio-Scientific Issues) model. The t-test results for the posttest scores yielded a sig. (2-tailed) value of $p < 0.001$. Consequently, H0 is rejected and H1 is accepted, indicating a significant difference in problem-solving skills between the control group (using PBL) and the experimental group (using PBL-SSI). These findings are consistent with the research of Alpianti & Amelia (2024) which reported a significant difference in the improvement of problem-solving skills before and after the implementation of a PBL model supported by SSI-based worksheets. Furthermore, this aligns with the study by Nugroho (2020), which compared inquiry-based learning for developing students' problem-solving skills and found that the integration of SSI in the experimental group yielded a more positive effect compared to the control group, where SSI was not integrated.

An effect size of $d=1.3$ indicates that the impact of the PBL-SSI model falls into the "very large" category. This substantial effect size can be attributed to the integration of PBL-SSI, which presents real-world problems, making it easier for students to visualize the issues at hand. Furthermore, the N-gain results for the experimental group were higher than those for the control group, demonstrating that the learning activities in the experimental group were more effective in enhancing students' problem-solving skills. These findings align with research by Hestiana & Rosana (2020) which indicates that the implementation of PBL-SSI is effective in improving scientific literacy and problem-solving skills among junior high school students. They are also consistent with the study by Kurniawan *et al*., (2024) which suggests that an SSI-oriented PBL model serves as an effective pedagogical tool for fostering problem-solving capacity. This is because the PBL-SSI model supports problem-solving through authentic issues relevant to students' daily lives, particularly environmental topics such as climate change and energy, thereby encouraging analytical and evaluative skills that facilitate more profound, scientifically-informed decision-making (Fatimah et al., 2025). Moreover, the SSI learning process enables students to improve their ability to analyze complex scientific systems alongside their social dimensions, a form of "socio-scientific thinking"—which is essential for understanding and addressing fundamental problems (Ke *et al.*, 2021). Consequently, the significant difference observed between the experimental and control groups further reinforces the conclusion that the integration of PBL and SSI plays a key role in building

students' conceptual understanding of work and energy through authentic socio-scientific phenomena.

Based on Figure 1, in the stage of understanding the problem, the experimental group achieved an N-Gain score of 0.83, which is higher than the 0.70 achieved by the control group. Prior to the intervention, both the control and experimental groups demonstrated a moderate level of initial ability in understanding the problem, though they were not yet able to articulate the issues comprehensively. The posttest results indicated that the students' final proficiency in understanding the problem was excellent in both groups, as evidenced by N-Gain scores that fall into the "high" category. This aligns with the research of Wulansari *et al.* (2025) which noted that the indicator for "understanding the problem" showed the highest average percentage increase, signifying that the students' grasp of the problems was very strong. These findings suggest that students in both groups became capable of identifying known information, formulating what was being asked, and recognizing the concepts relevant to the problems presented.

In the indicator of planning a solution to looking back at the solution obtained, students' answers began to vary. Not a few students were correct at the planning stage but were wrong when they reached the stage of implementing the plan in both the experimental and control groups. Students can plan the solution quite well by writing a solution plan using the work equation, but when implementing the plan, there are still shortcomings. This shows that even though planning is done well, understanding of concepts and accuracy in calculations still need to be improved. Meanwhile, at the stage of looking back at the solutions obtained, many participants did not do this, especially in the control group which had been completed if the answer numbers had been completed. This finding is also in line with research by Alpianti & Amelia (2024) which stated that the problem solving ability indicators in the experimental group using the PBL-SSI model were overall superior to the control group, especially at the re-examining stage where the difference was furthest compared to the others. From the N-Gain analysis of each indicator, it can be concluded that the experimental group is effective in improving students' problem solving skills, especially in business and energy material. This increase is also aligned and consistent across all indicators of problem solving ability.

In this study, the implementation of the PBL-SSI model in the experimental group involved presenting real-world issues relevant to daily life, thereby encouraging students to make science-based decisions. The social issues presented to the experimental group included a report from Kompas.com regarding a conflict between port laborers and Indonesian Navy personnel at the Port of Ambon, as well as scenarios concerning the use of forklifts for operational efficiency in logistics facilities and the role of kinetic energy in transport safety. In contrast, the control group, which utilized a standard PBL model, focused on problems derived from everyday phenomena, such as a car breaking down and being pushed by one or two people, a coconut falling to the ground, or the physical exertion experienced when accelerating a bicycle. In problem-based learning, these issues serve as a stimulus and an initial focal point for students to construct concepts (Muwonge & Joseph, 2024; Netekal et al., 2023). By using such problems as a stimulus and a central focus for learning, students are trained to develop problem-solving skills applicable to their daily lives. Furthermore, beyond fostering problem-solving skills, the

PBL approach also cultivates and enhances students' skills in communication and collaboration (Ningsih et al., 2025).

During the learning process, students in the experimental group appeared more engaged in discussions, sharing their opinions and raising questions about the issues under consideration. In the experimental group, specifically regarding the first issue, which concerned a conflict between port laborers and Indonesian Navy personnel at the Ampel port, the arguments presented by the students were quite complex. This is because the PBL-SSI (Problem-Based Learning with Socio-Scientific Issues) approach fosters higher-level problem-solving skills by requiring students to integrate physics concepts with social, economic, and safety considerations. Consequently, this encourages a broader range of arguments, deeper discussions, and decision-making processes grounded in both scientific evidence and social values. This contrasts with the control group, which utilized a standard PBL approach; for instance, when addressing a scenario involving a stalled car, initially pushed by one person and subsequently joined by a second, the inquiry focused solely on the question, "Why does the car become easier to push?" In this case, students simply needed to provide an explanation using concepts such as force, net force, and work. The responses tended to converge on a single, correct scientific explanation, which limited the scope for discussion and led students to focus primarily on conceptual problem-solving. Standard PBL problems often emphasize solutions based strictly on physics concepts, typically yielding a single, definitive answer. This is one reason why integrating SSI into PBL can enhance students' problem-solving skills more effectively than PBL without the inclusion of socio-scientific issues.

CONCLUSION

Based on the data analysis and discussion, integrating Socio Scientific Issues (SSI) into a Problem Based Learning (PBL) model resulted in significantly higher problem-solving scores for students studying the topic of work and energy, compared to students taught using a standard PBL model. An independent-samples t-test revealed a statistically significant difference in posttest scores ($p < 0.001$), with a large effect size (Cohen's $d = 1.3$). The experimental group achieved a higher mean posttest score than the control group. Overall, these findings suggest that PBL integrated with SSI is a promising approach for supporting students' problem-solving skills within the context of work and energy.

However, this study has limitations. The experimental conditions included several components that may have influenced students' problem-solving skills beyond the integration of SSI—such as the use of real-world contexts, discussions, multiple perspectives, and socially relevant scenarios. Future research could examine the application of PBL-SSI to other physics topics, such as fluid dynamics, current electricity, and waves, to investigate its utility across diverse subject areas. Further studies could also explore its impact on other competencies, including scientific literacy, critical thinking, scientific argumentation, and decision-making. Additionally, researchers should select SSI contexts that are relevant to students' lives and aligned with learning objectives, in order to foster scientific reasoning, evidence-based argumentation, and problem-solving skills.

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