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Development and Evaluation of the SISTEM (Socioscientific Issues Science Literacy Evaluation and Measurement) to Improve Students' Science Literacy

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Abstract

Low science literacy among Indonesian students, as evidenced by international assessments like PISA, underscores the urgent need to enhance their ability to connect scientific knowledge with societal issues. This challenge is exacerbated by a shortage of assessment tools that integrate scientific concepts with real-world phenomena, limiting students' capacity to apply science in addressing social problems. This study aimed to develop a socioscientific issues (SSI)-based science literacy assessment tool targeting junior high school students on the topics of heat, thermal expansion, and temperature. Employing a Research and Development (R&D) approach following the 4-D model (Define, Design, Develop, Disseminate), the study began with a needs analysis involving 15 teachers and 200 students across nine schools in Lampung Province. Guided by these findings, an SSI-based assessment instrument was designed and subjected to expert validation of content, construct, and language. The tool was then pilot-tested on 25 seventh-grade students at MTs N 3 South Lampung. Pre- and post-test evaluations revealed a significant increase in science literacy scores, from an average of 42.79 to 79.42. N-gain analysis indicated moderate improvement (0.64), while Cohen's d demonstrated a large

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effect size (2.70), confirming the tool's efficacy. The study concludes that the SSI-based assessment effectively enhances students' conceptual understanding and their ability to relate scientific principles to real-world contexts. It further recommends extending the tool's application to other science topics and diverse educational settings.

Keywords: Assessment Tool; Science Literacy; Socioscientific Issues; Heat; Thermal Expansion; Temperature

INTRODUCTION

Science literacy is a crucial skill for students in the 21st century, encompassing not only knowledge of scientific concepts but also the ability to apply this knowledge in daily life, especially when addressing increasingly complex social and global issues. In Indonesia, international assessments such as PISA have revealed the low science literacy among Indonesian students, reflecting a significant gap between students' scientific understanding and their ability to apply this knowledge to real-life contexts. Although Indonesia's ranking in science literacy has shown slight improvement in PISA 2022, the scores of Indonesian students remain inadequate, indicating that their science literacy is still at a low level (Fuadi et al., 2020; Latifah et al., 2022; Sabrina et al., 2021; Suparya et al., 2022).

This issue is primarily due to the lack of assessment tools that connect scientific concepts with relevant social issues in daily life. Most science literacy assessment instruments in Indonesia tend to focus on measuring students' understanding of basic theories without considering how these concepts are applied to solve real-world social problems. As a result, students face difficulty in linking science with the issues they encounter in daily life, particularly in the context of environmental changes, natural resource management, and sustainable technologies (Cintiati et al., 2024).

One approach that can enhance science literacy is the use of Socioscientific Issues (SSI), an instructional strategy that integrates science with relevant and often controversial social issues, such as climate change, renewable energy, and environmental pollution. The SSI approach not only teaches students about scientific theories but also encourages them to think critically about the social, ethical, and moral implications of applying scientific knowledge in society (Hernández-Ramos et al., 2021; Sadler et al., 2007). Although SSI has proven effective in improving students' critical thinking skills and their understanding of

science, its application in Indonesia remains limited, particularly in the assessment instruments used to evaluate science literacy (Genisa et al., 2020; Saija et al., 2022).

Given the current state of science education in Indonesia, the main issue faced is the low science literacy of students due to the lack of assessment tools that link scientific concepts with relevant social issues. Students are often only prepared to master basic scientific theories without being given the opportunity to apply this knowledge to solve real-world social problems (Safira et al., 2021; Suwono et al., 2022). This results in difficulties in connecting science with the challenges they face in daily life, particularly in the context of environmental changes, natural resource management, and sustainable technologies (Romli et al., 2024; Suwono et al., 2022).

Therefore, there is a need to develop a science literacy assessment tool that not only measures students' understanding of basic science concepts but also connects scientific knowledge with relevant social issues. This tool is expected to help students not only understand scientific concepts but also enhance their critical thinking skills and ability to make decisions based on social issues that require scientific understanding (Safira et al., 2021). Previous research has emphasized the importance of issue-based assessments in science education to increase student engagement and the relevance of scientific knowledge in their daily lives (Suwono et al., 2022).

This study proposes the development of a science literacy assessment instrument based on Socioscientific Issues (SSI) for the topics of heat, thermal expansion, and temperature. SSI as a learning approach that integrates science with social issues has the potential to improve science literacy among students (Karahan & Roehrig, 2017; Tidemand & Nielsen, 2017). In this assessment instrument, students will not only be tested on their understanding of basic physics theory but also on their ability to apply scientific knowledge to solve social problems related to scientific phenomena, such as the impact of temperature changes on the environment or the effects of renewable energy use on reducing global warming. This approach aims to engage students in meaningful and contextual science learning. Through SSI-based assessment, it is expected that students will be able to see the connection between science and their social lives, as well as develop the critical thinking skills needed to face future global challenges (Karahan & Roehrig, 2017). This instrument is also expected to contribute significantly to the development of more relevant and applicable science education in Indonesia.

The main objective of this study is to develop a science literacy assessment tool based on Socioscientific Issues (SSI) for the topics of heat, thermal expansion, and temperature for junior high school students. This tool aims to help students connect scientific knowledge with relevant social issues, improve their science literacy, and enhance their critical thinking skills in addressing social issues related to science. Additionally, this study also aims to test the effectiveness and practicality of the developed tool in the context of learning in schools across Indonesia.

METHODS

This study employed a Research and Development (R&D) design using the 4-D model developed by Thiagarajan, which consists of four main phases: Define, Design, Develop, and Disseminate (Figure 1). This model was chosen as it is suitable for developing an assessment tool based on Socioscientific Issues (SSI), aimed at improving science literacy among junior high school students in the topics of heat, thermal expansion, and temperature by connecting scientific concepts with relevant social issues (Suastrawan et al., 2021)

Figure 1.4-D model developed by Thiagarajan

1. Define (Identification Phase)

In this phase, a needs analysis was conducted to identify the issues and requirements for a science literacy assessment tool based on SSI. The analysis involved 15 teachers and 200 students from 9 schools spread across various regions of Lampung Province, including both urban and rural areas. Data was collected using questionnaires and interviews to understand the challenges faced by students and teachers in linking scientific concepts with social issues. The results of this analysis identified a gap between the theory taught in class and the application of these concepts to real-world social problems faced by students.

2. Design (Design Phase)

Based on the findings from the needs analysis, the science literacy assessment instrument based on SSI was designed. This instrument included questions linking scientific phenomena with relevant social issues, such as the impact of temperature changes on the environment or the use of renewable energy. The instrument also included a scoring rubric that measures students' ability to interpret data, make decisions based on scientific knowledge, and provide justifications based on scientific principles. Before testing, the instrument underwent expert validation on content, construct, and language aspects. The validation results showed very high validity, with average validation scores of 87% for content, 87% for construct, and 90% for language.

3. Develop (Development Phase)

The instrument designed was then tested on 25 students from Class VII at MTs N 3 South Lampung. The testing involved administering pre-test and post-test to measure the improvement in students' science literacy after using the SSI-based assessment instrument. The trial lasted for two weeks, during which students were given the opportunity to complete SSI-based tasks that integrated science with social issues. Feedback from students was also collected through questionnaires to assess their engagement, clarity of the instrument, and how well the material matched their understanding. Data Analysis: The data collected from the pre-test and post-test were analyzed using two statistical methods:

- N-Gain: To measure the improvement in students' science literacy. The N-Gain value was calculated using the following formula:

$$\text{N-Gain} = \frac{\text{Post-test} - \text{Pre-test}}{\text{Maximum Score} - \text{Pre-test}}$$

- Cohen's d (Effect Size): To measure the strength of the impact of the instrument on students' science literacy improvement. The effect size was calculated using the formula:

$$d = \frac{M_2 - M_1}{SD_{\text{pooled}}}$$

4. Disseminate (Dissemination Phase)

After the instrument was validated and tested, it was disseminated to other schools in Lampung Province to be used in science learning. A digital guide for teachers was also prepared to support the effective implementation of the SSI-based assessment tool. This guide provides instructions on how to integrate the tool into broader learning contexts and how to adapt the instrument to meet the needs of students and curricula.

Statistical Analysis

- N-Gain: Measures the improvement in students' understanding of the material after using the SSI-based instrument.
- Cohen's d (Effect Size): Measures the strength of the effect of the instrument on improving students' science literacy, indicating a large effect of the instrument's usage.

RESULTS

This study developed a Socioscientific Issues (SSI)-based science literacy assessment tool tested on seventh-grade students at MTs N 3 South Lampung. The assessment instrument was designed to enhance students' understanding of heat, thermal expansion, and temperature concepts while linking them to relevant societal issues. The research findings include three main parts: expert validation results, pilot test results (pre-test and post-test), and analysis of improvements in students' science literacy.

1. Expert Validation Results

The developed instrument was validated by two content experts and two educational evaluation experts. The assessment was conducted on three main aspects:

content, construct, and language. The validation results (Table 1) indicated that the instrument had very high validity across all three aspects, with the following average validation scores:

Table 1 Expert Validation Results

Aspect Evaluated	Average Score (%)	Validity Category
Content	87%	Highly Valid
Construct	87%	Highly Valid
Language	90%	Highly Valid

These results suggest that the developed assessment instrument is highly valid and suitable for field testing.

2. Pre-test and Post-test Result

The instrument was tested on 25 students from Class VII at MTs N 3 South Lampung. Before using the instrument, students took a pre-test to measure their initial knowledge of the material. After using the instrument, students took a post-test to measure the improvement in their understanding. The following results were obtained Figure 2.

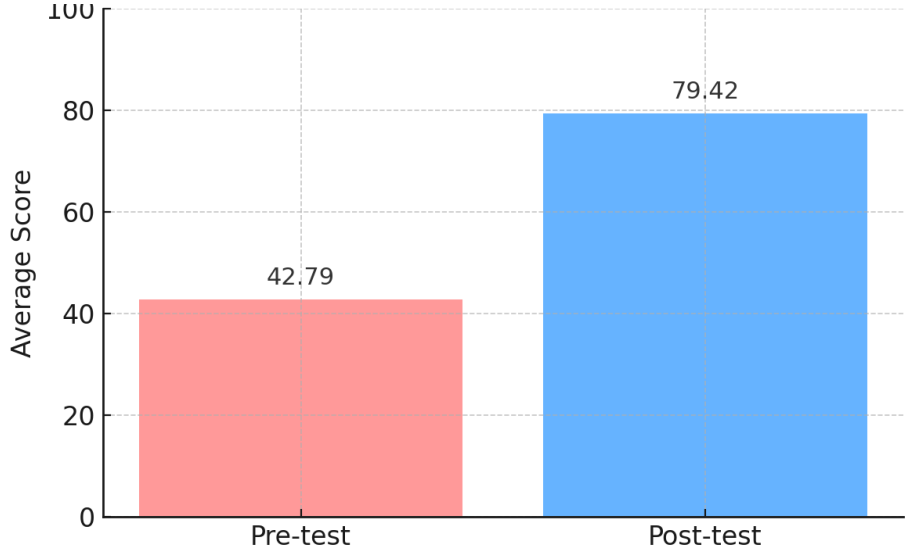

Figure 2 Pretes and post-test Average

The significant increase from 42.79 on the pre-test to 79.42 on the post-test shows that the SSI-based assessment instrument was effective in improving students' understanding of heat, thermal expansion, and temperature concepts. This result suggests

that students were better able to relate scientific concepts to real-world phenomena after using the instrument.

3. N-Gain and Effect Size Analysis

To further analyze the improvement in students' science literacy, N-Gain and Cohen's d (effect size) were calculated.

- N-Gain Analysis

  The N-Gain value was calculated using the formula:

$$\text{N-Gain} = \frac{\text{Post-test} - \text{Pre-test}}{\text{Maximum Score} - \text{Pre-test}}$$

With an average pre-test score of 42.79 and a post-test score of 79.42, and a maximum score of 100, then:

$$\text{N-Gain} = \frac{79.42 - 42.79}{100 - 42.79} = \frac{36.63}{57.21} \approx 0.64$$

Based on Hake (1999) classification, the N-Gain value of 0.64 falls into the moderate to high category, indicating that the use of the instrument significantly contributed to improving students' science literacy. An N-Gain value of 0.64 shows that the SSI-based assessment instrument resulted in significant improvement but is still in the moderate category. This means that, while there was clear improvement in students' understanding, there is still room for further enhancement in the use of this instrument, both in terms of the design of the questions and its application in the learning process.

Rahmani et al. (2024) and Husamah et al. (2022)) found similar results in their studies, suggesting that effective assessment tools help students connect scientific concepts with relevant social issues, thereby enhancing their critical thinking skills. Additionally, Ekantini & Wilujeng (2018) and Kartika et al. (2023) highlighted that the development of such instruments could improve students' ability to apply scientific knowledge in real-life situations and foster deeper engagement with the subject matter.

- Effect Size Analysis

To determine the magnitude of the impact of the instrument on the improvement of students' scores, Cohen's d formula was used:

$$d = \frac{M_2 - M_1}{SD_{\text{pooled}}}$$

$$SD_{\text{pooled}} = \sqrt{\frac{15^2 + 12^2}{2}} = \sqrt{\frac{225 + 144}{2}} = \sqrt{\frac{369}{2}} = \sqrt{184.5} \approx 13.58$$

$$d = \frac{79.42 - 42.79}{13.58} = \frac{36.63}{13.58} \approx 2.70$$

The Cohen's d value indicates the strength of the effect of the intervention on students' learning, where:

- d = 0.2 is considered a small effect,
- d = 0.5 is considered a medium effect,
- d = 0.8 is considered a large effect.

The Cohen's d value of 2.70, which is high, indicates that the impact of the Socioscientific Issues (SSI)-based assessment instrument on improving students' science literacy is highly significant. This means that the instrument has a strong effect on enhancing students' understanding of the physics material being taught and connecting it to relevant social issues, as discussed by Bicaj et al. (2024) and Güngör & Okur (2021)). This large effect size reflects that the assessment tool is not only effective but also has the potential to be widely applied in other schools. The application of SSI in science education has been shown to develop students' ability to apply scientific knowledge in practical contexts and improve overall science literacy (Güngör & Okur, 2021; Tidemand & Nielsen, 2017).

DISCUSSION

The results of this study indicate that the use of the Socioscientific Issues (SSI)-based assessment instrument for the topics of heat, thermal expansion, and temperature proved effective in improving science literacy among junior high school students. The average pre-test score obtained by students before using the instrument was 42.79, while the post-test score increased significantly to 79.42. This substantial improvement demonstrates that

the developed instrument successfully enhanced students' understanding of scientific concepts, particularly in basic physics, thus encouraging students to connect science with relevant societal issues. The findings align with research conducted by Nida et al. (2020), who reported a notable increase in science literacy among students using the SSI-based instrument, emphasizing its effectiveness in bridging the gap between scientific knowledge and real-world applications (Nida et al., 2020).

The N-Gain analysis, which resulted in a value of 0.64, indicates a moderate improvement in students' science literacy. Although this signifies meaningful progress, it suggests that further development of the instrument is warranted to elevate science literacy to higher levels. This result is consistent with findings by Hastürk & Ökkeşoğulları (2021), which indicate the instrument's effectiveness across various educational contexts and disciplines The increase in N-Gain reflects that the SSI-based instrument is quite effective in improving the understanding of science concepts at the junior high school level, which is inherently more complex compared to elementary education (Alat et al., 2023). Furthermore, the findings corroborate the assertion that SSI-integrated paradigms yield substantial educational benefits across different subjects, strengthening both science literacy and critical thinking skills (Zúñiga et al., 2021).

The calculation of Cohen's d, reaching a value of 2.70, indicates a very large effect size, underscoring that the impact of the SSI-based instrument on improving students' science literacy is highly significant. A Cohen's d value of 2.70 far exceeds typical values found in educational research, where a value of d = 0.8 is considered large. Such a prominent effect indicates that the SSI-based assessment instrument had a considerably strong impact on enhancing students' science literacy, which aligns with the findings of Wisdayana et al.(2025) concerning the positive correlation of SSI approaches with improvements in students' critical thinking skills.

However, despite these promising results, several limitations present in the study must be acknowledged. Firstly, the instrument was only tested in one school with 26 students, which constrains the generalizability of these findings. Future research involving a larger and more diverse participant pool across multiple institutions would be necessary to derive more conclusive insights regarding the effectiveness of this educational tool. Additionally, the two-week trial period limits the capacity to assess the long-term impacts of the SSI-based instrument on students' science literacy (Nida et al., 2020). Engaging in

prolonged studies would foster a more comprehensive understanding of both immediate and enduring educational outcomes derived from this approach (Hastürk & Ökkeşoğulları, 2021).

In conclusion, this study significantly contributes to the development of the SSI-based science literacy assessment instrument. This instrument not only measures students' comprehension of scientific concepts but also promotes critical thinking and the application of scientific knowledge to address pressing social issues. Given its adaptability for various other science topics, further exploration of the SSI-based assessment instrument in science education in Indonesia is warranted, suggesting the potential for the development of more extensive instruments suitable for different educational levels.

CONCLUSION

Based on the research findings, it can be concluded that the Socioscientific Issues (SSI)-based science literacy assessment instrument developed for the topics of heat, thermal expansion, and temperature has proven effective in improving science literacy among junior high school students. Significant improvement is evident in the average pre-test score (42.79) and post-test score (79.42), indicating that the SSI-based instrument helps students connect scientific concepts with relevant social issues. The N-Gain analysis, with a value of 0.64, indicates a moderate improvement in students' science literacy, while the Cohen's d value of 2.70 shows a very large effect size, indicating a strong impact of the instrument on improving students' science literacy skills.

This SSI-based assessment tool not only successfully enhances students' understanding of basic physics concepts but also fosters their critical thinking skills in addressing social issues. The findings of this study contribute to the development of more relevant and applicable assessment tools in science education, as well as improving students' understanding of how scientific knowledge can be applied in everyday life.

For future research, it is recommended to test this instrument in a larger number of schools with a more diverse sample and over a longer period of time. Further studies could also develop SSI-based instruments for other science topics and explore the long-term impact on science literacy and students' critical thinking skills. Therefore, it is expected that this instrument can be more widely applied in science education to improve the quality of education in Indonesia.

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