

Development of an Interactive Module Based on Socio-Scientific Issues (SSI) to Improve Students' Scientific Literacy

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ABSTRACT

Objective: This study aims to develop and evaluate an interactive module based on Socio-Scientific Issues (SSI) to improve science literacy among sixth-grade elementary students. Specifically, the objectives are to create a valid, practical, and effective learning module, to assess its impact on students' critical thinking and scientific discussion skills, and to compare the learning outcomes between experimental and control groups.

Method: This study employed a development research design to create an interactive module based on Socio-Scientific Issues for sixth-grade science learning. Validation was conducted through expert reviews on content and media aspects. Practicality was tested by involving teachers and media experts. Effectiveness was measured using a quasi-experimental design with pretest-posttest control group, analyzing learning outcomes through statistical tests. **Results:** The developed interactive module based on Socio-Scientific Issues was validated with an average expert score of 89%, indicating its suitability for use in science learning. Practicality tests with teachers and media experts yielded a score of 90%, confirming the module's ease of use. Effectiveness analysis showed a significant difference between the experimental and control groups ($p = 0.000$), with the experimental group demonstrating higher learning outcomes and improved science literacy skills. **Novelty:** This study introduces an innovative interactive module integrating socio-scientific issues to enhance science literacy in elementary students. Unlike conventional modules, it emphasizes critical thinking and real-life scientific debates, supported by validated content and media, making it both practical and effective in diverse classroom settings.

INTRODUCTION

A country with abundant natural resources does not automatically become a developed nation if it is not supported by high-quality human resources (Widiansyah, 2018). Quality human resources refer to individuals who not only possess comparative advantages but also have competitiveness and the ability to create new, beneficial innovations for themselves and their surrounding environment by utilizing their intellectual capacities. Such individuals are vital assets in the process of economic development and national progress (Adisaputro, 2020). Therefore, quality education serves as a strategic means to shape these individuals, as it provides opportunities for learners to continuously develop their spiritual, emotional, character, and intellectual abilities (Dodi, 2019). Indonesia's national education policy emphasizes holistic student development, character building, and 21st-century skills, as outlined in key documents such as Law No. 20 of 2003, the Merdeka Curriculum, and PISA performance reports. These policies highlight the urgency of strengthening students' literacy and critical thinking. However, despite the focus on science literacy, actual classroom practice remains largely teacher-centered, with limited student engagement and a lack of materials that contextualize science within real-life social issues. (JDIH, 2021).

The quality of a nation's human resources is a combination of both physical and psychological excellence, encompassing resilience, abilities, proficiency, and competence, which include knowledge, skills, and attitudes (Ansori, 2016). Learners are expected to actively develop their spiritual strength, self-discipline, individuality, intelligence, noble character, and the capabilities needed by society and the nation (Suprpto et al., 2022). In this era of Industry 4.0, students are expected to master 21st-century skills, which have become a focal point in the current educational landscape (WEF, 2016). The research employed a development methodology based on the ADDIE model. Instruments included validation rubrics for content and media experts, practicality questionnaires, and a science literacy test aligned with OECD (2025) indicators for scientific literacy. The test blueprint and validation rubrics are included in Appendix A. (OECD in Pratiwi et al., 2019). In 2015, the World Economic Forum agreed that mastery of six essential educational competencies is vital as foundational 21st-century skills (Ulfah et al., 2021). Recognizing its importance, the *Merdeka Curriculum* also emphasizes literacy across all areas, particularly in harnessing existing information and technology (Muliaman et al., 2022). Scientific literacy is especially important for students at this level, as those with high levels of science literacy are believed to have the capacity to understand and apply scientific concepts, analyze and explain phenomena with relevant evidence, evaluate information critically, and communicate conclusions accurately (OECD in Suryanti et al., 2020).

Science and social studies are fields of knowledge that examine both biotic and abiotic elements of the universe, as well as human behavior and its impact. In the *Merdeka Curriculum*, these disciplines are integrated into a subject called IPAS (Natural and Social Sciences), with learning outcomes (*Capaian Pembelajaran* or CP) tailored to each educational phase. IPAS aims to foster students' curiosity and understanding of their surroundings, encouraging them to solve problems using scientific methods, which involve strong interest, reasoning, deep comprehension, and sound decision-making (Sagendra, 2022). Critical thinking is essential for identifying and solving problems by applying scientific theories and principles, playing a key role in enhancing students' science literacy (Aiman & Ahmad, 2020). Science literacy is crucial in today's world, as it enables individuals to gain a deep understanding, communicate effectively, and apply scientific knowledge to address real-life challenges (Daniah, 2020). Mastery of science literacy enables individuals to become capable and high-quality thinkers who can reason, innovate, solve problems, and effectively utilize technology (Mufida & Teguh, 2018).

According to the 2022 Public Education Report, 61.53% of elementary students in Indonesia had literacy skills above the minimum standard – an 8.11% increase from 2021. However, this still falls within the moderate category (40%–70%), indicating that literacy achievement remains suboptimal (Ministry of Education, 2023). In science literacy, Indonesia consistently ranked low in PISA surveys from 2000 to 2018. Although there was a slight improvement in reading and science, and a more notable rise in mathematics, the 2018 results showed an overall decline, especially in reading (Wuryanto & Abduh, 2022). Observations and interviews at Kyai Ibrahim Elementary School in Surabaya revealed that learning remains largely teacher-centered, relying on lectures and note-taking methods, with limited student engagement (Ashari & Mariana, 2022). Despite

using printed Merdeka Curriculum textbooks, many of the included QR codes are inaccessible, and some required materials are missing. As a result, students tend to memorize rather than apply scientific concepts, limiting their scientific skills. Faturrohman and colleagues emphasize that weak literacy is often due to inadequate curriculum models, ineffective teaching methods, and insufficient learning tools (Fauziah et al., 2019). Initial 2023–2024 data at Kyai Ibrahim Elementary School showed that 61.22% of 5th-grade students scored below the minimum standard in science literacy.

Reading media containing comprehensive knowledge for teachers and students is a crucial element in effective learning. Currently, the main teaching material is a printed textbook aligned with the Merdeka Curriculum. However, analysis shows that these textbooks lack emphasis on Socio-Scientific Issues (SSI), a learning strategy aimed at stimulating intelligence, behavior, and understanding of science within social contexts (Zeidler et al. & Nuang C. in Tumangkeng, 2022). SSI is effective in interactive digital learning development because it fosters scientific literacy by sharpening students' skills and moral reasoning to solve real-world problems (Widodo et al., 2019).

This approach supports students' skill development through structured learning phases. As Rukman & Samsudin (2022) note, creating specific teaching modules allows educators to tailor materials using chosen approaches to enhance learning. The limitations of printed teaching materials, therefore, open opportunities for teachers to design adaptive reading media tailored to current needs and contexts.

Although various learning modules have been developed to improve students' scientific literacy, few studies have explicitly integrated the Socio-Scientific Issues (SSI) approach into interactive modules for elementary education, especially on the topic of natural resource potential. Previous modules, such as Android-based e-modules (Rofiyadi & Handayani, 2021) and SSI-based biology materials (Septiningrum et al., 2021), have focused on secondary education and specific scientific content (e.g., circulatory system or viruses), without contextual alignment with the Merdeka Curriculum for primary schools. While some studies have explored the use of SSI-based materials at the secondary level, little work has been done on interactive modules that integrate Socio-Scientific Issues within the elementary science curriculum, particularly in line with the new IPAS subject under the Merdeka Curriculum. This study aims to address that gap by designing and validating an interactive SSI-based module tailored for 5th-grade students, focusing on ecosystem themes and the development of science literacy.

Teachers play a crucial role in utilizing learning media; however, it is undeniable that some educators still face difficulties in using such tools effectively. Several challenges hinder teachers from developing and implementing instructional media, including: (1) lack of knowledge on how to use educational media, (2) the cost involved in producing the media, and (3) the complexity of the subject matter, which makes it difficult for teachers to design appropriate media. These problems often stem from teachers' limited understanding of how to develop learning media. Nevertheless, the teacher's role in integrating media into the teaching process has a significant positive impact. It not only facilitates students' learning but also allows teachers to explore effective teaching

strategies and apply diverse learning models to achieve optimal learning outcomes (Mukarromah & Andriana, 2022).

Inspired by the findings of the two studies above, the author was motivated to conduct a research project by developing a module that combines both references—namely, an interactive module based on the Socio Scientific Issues (SSI) approach, focusing on a different subject from previous studies: natural resource potential.

RESEARCH METHOD

The type of research conducted uses the Research and Development (R&D) method, which is an approach designed to produce learning products as well as to assess their effectiveness and feasibility (Purnama, 2016). Another opinion defines development research as activities that involve the creation, discovery, and improvement of new methods, products, and services, as well as investigating how these innovations address market needs and demands (Astutik et al., 2021).

This development research utilizes the ADDIE development model. The ADDIE model is a development model introduced by experts Dick and Carey (1996). In this research development process, the model will be implemented through a series of stages outlined in ADDIE: Analyze, Design, Develop, Implement, and Evaluate, as described below:

Analysis Stage (Analyze)

In the initial step, the researcher prepares several instruments to support this phase, including a questionnaire instrument used to collect data from students or prospective users, specifically the fifth-grade students and teachers of SD Kyai Ibrahim, to understand their needs and characteristics. An interview instrument is also used to gain deeper insight or information from students or users about their needs or the problems they face. Additionally, an observation instrument is used to directly observe the situation and gain a better understanding of existing needs and challenges. Through observations, interviews, and the distribution of student needs analysis questionnaires, it was found that in IPAS (Natural and Social Sciences) learning, both teachers and students rely solely on printed IPAS teaching materials aligned with the *Merdeka Curriculum*, which currently does not include a socio-scientific issues (SSI) approach. Teachers and students are also unfamiliar with this approach. Meanwhile, the media used in the classroom are mostly sourced from Google and YouTube.

Design Stage

Based on the data gathered during the analysis phase, the second step is the **design phase**, consisting of: a.) **Module Outline**: This study introduces a novel approach through the development of an interactive IPAS module based on SSI, which not only presents scientific content but also encourages students to evaluate social issues within their environment critically. The module is designed to enhance scientific literacy through problem-based learning supported by digital media, and is tailored to the needs and local contexts of elementary school students. This approach remains underexplored in Indonesia's basic education context, making it a unique contribution to the literature.

b.) **Learning Content Design:** the module contains tutorials aligned with a problem-based learning structure, involving: guiding students in identifying and solving real-life problems, encouraging student-led inquiry and research, supporting both individual and group investigations, facilitating product development and presentation, helping students analyze and evaluate the solution process.

Development Stage

During the **development stage** of the ADDIE model, various software (e.g., Flip PDF Corporate, Canva) and hardware (e.g., laptops, mobile phones, speakers) were used to create multimedia content. Additional resources such as textbooks, articles, and lesson packages were also utilized. According to **Rika Dyanita Sari et al. (2021)**, the development process involves: a.) **Initial Product Draft:** A prototype module was developed based on the socio-scientific problem context, including core material, teaching modules, and assessment tools. These were distributed online to students to enhance logical thinking and were reviewed by expert validators; b.) **Content Validation:** Experts—including content lecturers, media specialists, and teachers—assessed the module and instruments to determine their validity and relevance in terms of both content and design. Revisions were made based on feedback to improve the product's quality; c.) **Limited Trial:** A small-scale trial was conducted with six students of varying abilities from classes VA and VB at SD Kyai Ibrahim. This test aimed to ensure the clarity, usability, and effectiveness of the module before full implementation.

Implementation Stage

In this stage, the interactive IPAS module based on socio-scientific issues was implemented in the experimental class, specifically Class VA of SD Kyai Ibrahim Surabaya. The implementation involved using the developed module in a full-scale classroom setting, following the designed lesson plan. The process was supported with a user guide to ensure proper use and observation sheets to monitor how the module functioned in real situations. The data collected from this stage were then analyzed to assess the module's effectiveness.

Evaluation Stage

During the evaluation phase of the ADDIE development model, various instruments, including questionnaires, interviews, observations, tests, and evaluation tools, were used to gather relevant data for detailed analysis. The evaluation consisted of two key types (Rika Dyanita Sari et al., 2021): a.) **Formative Evaluation.** Conducted at every phase—analysis, design, development, and implementation—this evaluation provided continuous feedback to improve the product throughout its development; b.) **Summative Evaluation:** Performed after the module was fully developed and implemented, this evaluation aimed to assess the overall effectiveness and impact of the socio-scientific issue-based interactive module on student learning.

To refine the learning product developed in the form of a science module that promotes sociological awareness, it is essential to carry out a systematic item testing process. This item elimination phase consists of two stages: a limited-scale trial and a broader field trial. Each stage aims to evaluate the product's effectiveness and ensure its

alignment with the intended educational objectives. The results from these trials help determine necessary revisions to enhance the quality of the instructional module. The limited-scale trial involves six students: two with low academic ability, two with moderate ability, and two with high ability. This diversity is intended to identify the strengths and weaknesses of the developed product before testing it on a larger scale. The large-scale trial is conducted using two different classes: Class VA as the experimental group and Class VB as the control group at SD Kyai Ibrahim Surabaya. At this stage, Class VA explores the revised intuitive science module that integrates sociological issues, while Class VB uses conventional printed textbooks typically used in schools.

This study involved 34 fifth-grade students from SD Kyai Ibrahim Surabaya, divided into two groups: Class VA (experimental group) and Class VB (control group). The students were aged 10–11 years, with a balanced gender distribution. The school is a public elementary institution located in an urban area, with students coming from diverse socio-economic backgrounds. In the even semester of the 2024–2025 academic year, with the topic "Harmony in the Ecosystem." This study employed two data collection methods: tests and non-tests. The test method was used to assess improvements in students' scientific literacy, while the non-test method was conducted to analyze the readability and feasibility of the interactive module product and lesson planning. The instruments used in this research and development included validation sheets for product assessment, filled out by informatics and technology expert lecturers using a five-point scale, as well as practicality validation sheets completed by media experts and practitioners in science and technology education. The limited trial phase assessed aspects such as effectiveness, interactivity, efficiency, and creativity. These validation sheets were used prior to large-scale implementation to ensure that the aspects and indicators being measured were appropriate. Additionally, the lesson plan or teaching module validation aimed to evaluate the suitability and feasibility of the planned learning process, with inputs from subject matter expert lecturers and school principals (teacher leaders).

A post-learning questionnaire was used to evaluate the effectiveness of the module and the learning process, identify students' challenges, and gather suggestions for product improvement. It also played a role in measuring student motivation and participation, providing useful data for educational research, and helping teachers tailor their teaching methods to students' needs. The instrument validation sheet for scientific literacy questions assessed the relevance, construction, and language of the test items and was completed by expert science lecturers. In the large-scale trial, this validation aimed to determine the accuracy and validity of the developed instrument or product. The scientific literacy test itself consisted of essay-type questions guided by specific scientific literacy indicators.

The interactive module based on Socio-Scientific Issues (SSI) that has been developed will be evaluated by a team of experts, consisting of a media expert and a subject matter expert, through a validation sheet. The media expert validation sheet includes assessment aspects related to the module content, clarity of information and images, as well as layout elements such as color and font type. Meanwhile, the subject matter expert validation sheet focuses on the relevance, accuracy, and up-to-dateness of the presented material. The data from the validation sheets assessed by the validators will then be analyzed by

calculating the average score of each aspect using a formula cited from the journal by Aswardi et al. (2019).

The assumptions that samples are randomly selected and populations are normally distributed are often treated as formalities in analysis (Sari et al., 2017). A normality test is conducted to determine whether data follows a normal distribution, using the Kolmogorov-Smirnov test in SPSS version 21. Data is considered normally distributed if the Sig. value is greater than 0.05. A homogeneity test is used to assess whether population variances are equal – an essential requirement for independent sample t-tests. If the data is normally distributed and the variances are equal, the data is considered homogeneous, and no further testing is needed. In development research, product effectiveness can be measured by comparing outcomes before and after its use. An Independent T-Test is used to analyze differences in science literacy improvement. A p-value less than 0.05 indicates a significant difference, demonstrating the product's effectiveness. (Sianturi, 2022).

RESULTS AND DISCUSSION

Results

This study focuses on "*Developing an Interactive Module Based on Socio-Scientific Issues to Enhance Students' Science Literacy*" conducted at Kyai Ibrahim Elementary School, Surabaya. The research involved 34 students, with class V-A as the experimental group and class V-B as the control group, carried out on January 13, 2025. The learning process included six face-to-face sessions: two for product application and two for pre-test and post-test assessments conducted before and after classroom learning.

This step was undertaken to assess the validity of the interactive module. The validity test involved two validators – a subject matter expert and a media expert – who assessed the instrument using a five-point scale (1 to 5) along with suggestions. This validation was conducted before limited and wider trials. The results from the experts' reviews are presented in Table 1.

Table 1. Validity Analysis of the Interactive Module Based on Socio-Scientific Issues					
No	Assessment Type	Maximum Score	Achievement Level	Score Obtained	Category
1	Subject Matter Expert	100	90–100 80–89 65–79 55–64	87	Valid
2	Media Expert	100	90–100 80–89 65–79 55–64	92.3 (converted)	Very Valid

Note: Media Expert score (92.3) may be converted to a 100-point scale for comparison purposes.

Based on the data in Table 1, the developed interactive science module based on Socio-Scientific Issues is considered **very valid** if the score falls within the 90–100 range. The media validation instrument, assessed by the subject matter expert, evaluated aspects

such as learning objectives, relevance, interactivity, material packaging, visuals, language, and more. The validation sheet is available in the appendix. The subject matter expert evaluated the module using four criteria: self-instruction, self-contained, adaptive, and user-friendly, resulting in a score of 87, which falls in the **valid** category (80–89 range). Suggestions included simplifying long sentences, improving image clarity, and using more understandable examples—all of which have been revised. The scientific literacy assessment instrument was also declared valid, serving as a parameter tool with established variables. The results of this validation are illustrated in Figure 1.



Figure 1. Product Validity Diagram by Subject Matter Experts

The validation of the interactive module based on Socio-Scientific Issues by the media expert also showed strong results. The validation instrument assessed aspects such as size, cover design, and content layout, scoring 92—categorized as highly valid (90–100 range). The expert suggested using images related to students' surroundings. Content validation was divided into three aspects: size, cover design, and content layout, with an overall score in the 80–89 range, categorized as valid. The validation results from the media expert are shown in Figure 2.

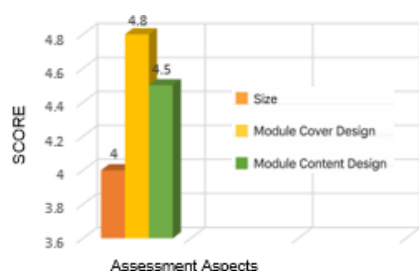


Figure 2. Product Validity Results by Media Expert.

Based on the assessment analysis by the media expert, the developed module was evaluated across several aspects—namely size, cover design, and content layout. Overall, it received a score of 60, falling within the 90–100 range, which is categorized as highly valid and suitable for use. The test instrument was evaluated to ensure it provides consistent and reliable results over time. Cronbach's Alpha formula was used to test internal consistency, where a value above 0.6 indicates acceptable reliability. The learning plan was assessed to ensure it meets educational standards and can be effectively implemented. A student questionnaire was distributed after the lesson to evaluate the effectiveness of the learning process, gather student experiences, and identify areas for

improvement. A small-scale trial was conducted to measure the readability of the "IPAS Interactive Module Based on Socio-Scientific Issues." It involved six students: two with low ability, two with average ability, and two with high ability.

The normality test was conducted to determine whether the pretest and posttest data follow a normal distribution. If the data are normally distributed, parametric statistical analysis such as the t-test can be applied. The results of the normality test are presented in Table 2.

Table 2. Normality Test Results

Test Type	Group	Statistic	df	Sig.
PRE-TEST	Control Class	0.093	34	.200*
	Experimental Class	0.120	34	.200*
POST-TEST	Control Class	0.145	34	0.066
	Experimental Class	0.137	34	0.105

*Note: *Significance values greater than 0.05 indicate normal distribution.

After the normality test was conducted to determine whether the data were normally distributed, the next step was the homogeneity test to assess whether the data groups have uniform variances or show significant differences. The results of the homogeneity test can be observed in Table 3.

Table 3. Homogeneity Test Results

			Levene Statistic	df1	df2	Sig.
PRE-TEST	Based on Mean		0.206	1	66	0.652
	Based on Median		0.166	1	66	0.685
	Based on Median and with adjusted df		0.166	1	65.538	0.685
	Based on trimmed mean		0.195	1	66	0.660
POST TEST	Based on Mean		0.958	1	66	0.331
	Based on Median		1.020	1	66	0.316
	Based on Median and with adjusted df		1.020	1	57.688	0.317
	Based on trimmed mean		1.013	1	66	0.318

The N-gain calculation for each science literacy aspect aims to measure learning improvement more specifically. It helps evaluate the effectiveness of instruction per aspect, identify which areas show the most significant gains, and highlight those needing improvement. High N-gain values indicate strengths, while low values suggest weaknesses that may require intervention. The N-gain results for each aspect are shown in Table 4.

Table 4. N-Gain Results by Science Literacy Aspect

No.	Aspect	Indicator	Pre-test	Post-test	N-Gain	Category
1	Content	Identifying Scientific Issues	55.9	84.3	0.65	Medium
2	Context	Clarifying Scientific Phenomena	18.7	66.0	0.58	Medium
3	Process	Describing Scientific Evidence	21.7	64.3	0.54	Medium
Average			32.1	71.5	0.59	Medium

Discussion

The developed interactive module based on socio-scientific issues integrates social and scientific aspects in learning to enhance students' critical thinking by linking science concepts to real societal problems. The module follows step-by-step stages to improve critical thinking skills and students' awareness of socially impactful scientific issues, supported by Lev Vygotsky's social constructivism theory, emphasizing social interaction in learning (Salsabila & Muqowim, 2024). The stages include issue identification, scientific concept exploration, discussion and argumentation, decision-making, and reflection, all integrated using Flip PDF Corporate software. Its feasibility was tested through expert assessments by content and media specialists, supported by Richard Mayer, Alesi, and Trollip's theory on development validation, which evaluates learning media based on multimedia construction and content (An et al., 2025). The content expert validator, Prof. Dr. Suryanti, M.Pd., assessed module feasibility via a rating scale instrument covering six validity aspects: cover, format, content, language, practicality, and effectiveness (Komang Wiratama & Gede Margunayasa, 2021). Criteria included cover and identity suitability, alignment of indicators with material, language quality, media practicality, and effectiveness related to media use. Further, content experts examined module construction, completeness, flexibility, and accessibility (Plom in Desyandri, 2019). According to Table 4.1, content expert validation showed an 87% feasibility score with suggestions to revise lengthy questions and add appropriately sized images for various devices, as illustrated modules motivate students through thematic visuals and appealing color combinations (Wibowo in Nuryani & Surya Abadi, 2021). These results align with Lestari et al. (2023), who developed an electronic module via Flip PDF Corporate Edition, validating with questionnaires and percentage analysis, obtaining an average material validation score of 87.14%.

The developed product, an interactive module based on socio-scientific issues, was designed with consideration for aspects such as size, cover design, and content layout.

Before media expert validation, an assessment grid covering aspects and indicators was created, using a 1 to 5 scale. Media validation was conducted by a qualified expert in information technology and educational products, Dr. Julianto, S.Pd., M.Pd., who rated the module's feasibility at 85.28% and suggested using images familiar to students, supported by Daryanto (2013) who emphasized images' power to engage learners. He also recommended adding mini labs for each subtopic, consistent with Nurlatifah et al. (2023) and Mayer's theory that e-modules combining animation and narration are more effective than text alone. Modules allowing user interaction through quizzes or simulations enhance deeper understanding (An et al., 2025). This approach integrates science, technology, engineering, and mathematics (STEM) to strengthen critical thinking, problem-solving, and innovation skills. These validation results align with Rahmayanti & Andayani (2023), who reported that e-module validation by media, content, and language experts yielded average scores of 82 for lesson plans and 80 for SSI-based e-modules, both rated very valid. Based on validations by content and media experts and relevant feedback, the developed interactive socio-scientific issues module is deemed feasible and suitable for learning.

The practicality test ensures that an innovation is not only theoretically valid but also easy to apply, measuring how easily, efficiently, and effectively users can utilize the product as intended. Before practicality validation, an assessment grid was prepared to evaluate aspects of effectiveness, interactivity, efficiency, and creativity, rated on a scale of 1 to 5 (Izzania et al., 2024). The module scored 88% (valid) with suggestions to link content to daily phenomena and science literacy, add videos, and include triggering questions for each phenomenon (Rahmayanti & Andayani, 2023; Suryani, 2019). Based on expert feedback, the socio-scientific issues interactive module is practical to use. Designed to meet students' needs, practicality was confirmed through surveys with a practical category (Nieveen, 1999; Sugiyono, 2017). This aligns with Norbert Wiener's cybernetics theory emphasizing feedback and easy information processing to support optimal interaction (Syuhada, 2022). Practicality testing by a practitioner, Anita Rahmawati, S.Pd.I, also used the same assessment aspects and scale (Izzania et al., 2024), yielding a 90% score (very practical) with suggestions to add navigation icons for easier use, supported by Putri et al. (2021). Student surveys rated 92% (very practical) with recommendations for more images and videos. These results align with Setiadi & Putra (2021), where SSI-based science modules received high feasibility scores from language (94.66%), content (91.7%), and media experts (97.7%), with student practicality at 82.87% and teacher response at 73.71%. Based on practicality validations from media experts, practitioners, and students with improvements made, the interactive socio-scientific issues module is declared highly practical for learning.

The interactive module addressing socio-scientific issues is specifically designed to strengthen students' science literacy. Its effectiveness is measured using test instruments that assess student achievement improvements, supported by Piaget and Vygotsky's theories emphasizing active learning through individual interaction with the environment and social relationships (Dewi, 2013). Essay-type questions were chosen over multiple-choice items to capture better students' reasoning, argumentation, and ability to evaluate real-world socio-scientific issues—core skills emphasized in SSI-based learning. This aligns with previous recommendations by Saidah & Malichatin (2023). The test consists of 10 essay questions. Before validation, a scoring rubric aligned with

required standards was prepared and validated by content expert Prof. Dr. Suryanti, M.Pd., who rated the test's feasibility at 87.2% (worthy). Suggestions included italicizing or underlining foreign terms, adjusting operational verbs for C4-level questions, and adding apperception or problems before questions to suit the cognitive level C4. This aligns with Putra et al. (2021), who developed instruments for critical thinking and science literacy in grade 4 students with strong content validity (0.76) and reliability (0.92), deemed effective for learning. The validated instrument was then tested on 30 students in class V-C, outside the research sample, to confirm validity and reliability – key qualities including objectivity, ease of administration, and cost efficiency (Arikunto, 2021). Validity testing via SPSS 21 showed significant correlations ($p < 0.01$) with all 10 questions' r -values exceeding the r -table value of 0.36, confirming the test's validity. This supports Arikunto's (1996) definition of validity as the degree to which a test measures what it is intended to measure.

The next step was testing the reliability of the test items using Cronbach's Alpha via SPSS 21, consistent with Nuswowati et al. (2010), who emphasize the importance of validity and reliability in ensuring effective evaluation instruments. The test yielded a Cronbach's Alpha of 0.956, indicating very high reliability, well above the required threshold of 0.6. This high value reflects excellent internal consistency, meaning each item consistently measures the same concept, ensuring the data's trustworthiness for research use. This aligns with Khasanah & Setiawan (2022), who found a science literacy test valid (r calculated = 0.607 > r table = 0.324) and reliable (Cronbach's Alpha = 0.758 > 0.6) using SPSS with a sample of 37 students. Based on these results, a strong correlation exists between each item and the total score, indicating the instrument's high quality, reliability, and validity in assessing students' science literacy. Therefore, the research results are dependable and suitable for further analysis.

The next stage is the feasibility assessment of the lesson plan (RPP). This structured process involves designing and organizing activities to achieve set goals (Fibra & Indrawadi, 2021). The RPP is designed by adjusting and determining learning objectives, materials, methods, models, and approaches (Ni'mah et al., 2018). A rubric for assessing the RPP's feasibility was created and evaluated by content expert Prof. Dr. Suryanti, M.Pd., and the principal (teacher leader) Aan Minanur Rohman, M.Pd.I. The content expert rated it 84% (valid), while the principal gave 95% (very valid). The RPP met most criteria, including curriculum alignment, clarity of objectives, suitability of methods and strategies, and completeness, making it suitable for use. Suggestions included adding student appreciation at the beginning, middle, and end of lessons. This result aligns with Ferdiana Sari & Ekohardi (2021), who found expert validation percentages of 91.33% for RPP, 91.26% for materials, 95.80% for media, and 91.59% for student response questionnaires.

The final part is student responses after learning. According to behaviorist theory, student responses occur as reactions to stimuli given by the teacher (Sudarti, 2019). The teacher provides questions or material, and students respond based on their understanding. Engaging learning increases student enthusiasm, helping them absorb the material better. This is reflected in student responses during learning, seen as social interaction responding to environmental or interpersonal stimuli (Maharani & Widhiasih in Kartini & Putra, 2020). First creating indicators developed the student response questionnaire for students to evaluate by checking items. It was then distributed to class

V-A students after using the socio-scientific issues (SSI) approach and the developed module. Results show an average score of 88.7, categorized as good. This aligns with research on PBL-based math e-modules, where teacher responses averaged 80–82%, and student responses averaged 87.2%, indicating high acceptance. The student response data suggest that using the SSI-based interactive module is effective in improving learning quality, as shown by meeting most required indicators.

To determine the effectiveness of the developed interactive module, instrument testing was conducted first, followed by a small-scale trial with 6 students of varying abilities: 2 high, 2 medium, and 2 low ability. After treatment, students completed a science literacy evaluation to provide initial feedback and identify potential errors before larger-scale testing (Lutfah, 2023). The small-scale trial yielded an average score of 90, categorized as very good. This score indicates that most participants rated the module highly in effectiveness, efficiency, user satisfaction, and feasibility. Similarly, Kadir et al. (2024) reported an average positive response of 93% to a Problem-Based Learning e-module on environmental changes for class X-5, indicating that the module was well-received, easy to understand, engaging, and effective. Following the small trial, one improvement was made by adding the quiz title "Science Literacy Practice Questions" to the module's quiz page.

Normality testing is conducted to determine if data follows a normal distribution, where mode, mean, and median are centered symmetrically. Traditionally, data with $n > 30$ is assumed normal, but this is not always accurate, so testing is necessary (Fahmeyzan et al., 2018). Using the Kolmogorov-Smirnov test (Figure 4.5), both experimental and control class data were normally distributed. For the experimental class, pretest statistics were 0.120 (sig. 0.200) and posttest 0.137 (sig. 0.105), indicating no significant deviation (sig. > 0.05). Control class results were similar, with a pretest of 0.093 (sig. 0.200) and a posttest of 0.145 (sig. 0.066). Normal data meets assumptions for parametric tests (Fatwa et al., 2025).

Homogeneity was tested with Levene's test (Figure 4.6). Significance values of 0.65 and 0.33 ($p > 0.05$) confirm variance homogeneity between groups, supporting further analysis. Homogeneity ensures equal population variance, validating analysis reliability (Widhiarso, 2011). This aligns with Fatwa et al. (2025), reporting Levene's Test significance of 0.326, confirming no significant difference in variance between experimental and control groups.

Before the large-scale trial, N-gain and N-gain per science literacy aspect were measured to assess student learning improvements after intervention, allowing comparison between experimental and control classes (Coletta & Steinert, 2020). Using pretest and posttest data analyzed via SPSS, the control class had an average N-gain of 0.5 (medium), while the experimental class scored 0.7 (high), indicating the experimental method was more effective in enhancing student understanding and achievement. This supports Widagdi (2022), who found the SAVI learning model with flashcards improved student outcomes significantly.

N-gain was also analyzed by the literacy aspect. The content aspect, involving identification of scientific issues, showed a medium gain of 0.65, influenced by the interactive socio-scientific issues module fostering student engagement and questioning (Rohmawati et al., 2018). The context aspect, clarifying scientific phenomena, improved with an N-gain of 0.58, supported by high student critical thinking scores (93.3) during

discussions (Rohmawati et al., 2018; PISA definition). Nikmatur Rohmaya et al. (2023) reported a similar medium gain of 0.49 for evaluating and designing scientific inquiry with positive student response (87%). The process aspect, describing scientific evidence, showed a gain of 0.59, attributed to active student participation in practical work aided by the interactive module, reflected in high student response scores (92) (Nikmatur Rohmaya et al., 2023). Overall, all literacy aspects improved at a medium level, confirming the module's effectiveness in enhancing science literacy.

The independent sample t-test is used to analyze the difference in means between two unrelated groups, aiming to determine if the difference is statistically significant (A. D. Putri et al., 2023). Based on Figure 4.9, the test yielded a significance value (Sig) of 0.000, indicating a statistically significant difference between the two groups, as $\text{Sig} < 0.05$. The mean difference was -8.882, with the first group scoring lower than the second. At 95% confidence, the mean difference ranged from -5.44895 to -12.31576, confirming significance. This aligns with Wibisana et al. (2022), who reported an increase from a pretest mean of 50.47 to a posttest mean of 76.25, with an N-gain of 0.52 (medium category), concluding that the developed e-module significantly improved student learning outcomes. Similarly, Fatwa et al. (2025) found a t-value of 7.405 with $\text{df} = 62$ and $\text{Sig. Two-Tailed} < 0.001$, indicating a significant difference in science literacy between experimental and control groups.

CONCLUSION

Fundamental Finding: The interactive module based on Socio-Scientific Issues (SSI) developed in this study was found to be valid, practical, and effective in enhancing the scientific literacy of elementary students. Validation results from content and media experts showed an average score of 89% (highly valid), practicality tests with teachers and students yielded an average of 90% (highly practical), and the module's effectiveness was confirmed through a significant difference in learning outcomes between the experimental and control groups ($p = 0.000$). The module successfully fostered student engagement in scientific discourse and improved their understanding of science in real-life social contexts. **Implication:** This development research produced an interactive module based on socio-scientific issues, complete with a valid, practical, and effective lesson plan and assessment for teaching science in sixth-grade elementary school. **Limitation:** However, the research has some limitations. One major limitation is that the module must be accessed through devices with internet data, meaning it requires online operation. Besides having devices such as smartphones, laptops, or tablets, sufficient internet quota is also needed for the module to be used effectively. This poses a challenge in areas with limited or no internet access, as not all schools across Indonesia have internet connectivity, and not all students own personal devices. Additionally, school policies regarding the use of phones in elementary schools vary, which may further restrict module usage. **Future Research:** The interactive module based on Socio-Scientific Issues (SSI) can be utilized in science learning to enhance student participation in scientific discussions related to everyday life. However, its use requires support from teachers to guide students in developing critical thinking skills and making decisions based on scientific evidence. Several factors need attention for effective implementation. First, the module must align with the current curriculum standards to ensure its

relevance and applicability. Second, both teachers and students must be prepared; teachers need to understand the SSI concept and discussion-based learning methods to maximize the module's benefits. Third, continuous evaluation and adjustment of the module are necessary to maintain its effectiveness in improving students' science literacy. For future research, further development of the module could focus on enhancing its interactive features, such as integrating digital technology or computer-based simulations. Additionally, the module's effectiveness should be tested across various educational levels and school environments to observe broader impacts. Finally, research could explore how SSI can be integrated across disciplines, for example, combining science learning with social ethics.

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