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Development of Socio-Scientific Issues (SSI) Based Student Worksheets on Climate Change Material: Evaluation of Practicality and Effectiveness on Students' Scientific Attitudes

Rabiatul Hasanah[1*], Ahmad Yadaeni[1], Dedi Riyan Rizaldi[1], Mahsur[2]

[1] Physics Education Study Program, Al-Manan NU Islamic Institute, East Lombok, East Lombok, Indonesia.
[2] Early Childhood Islamic Education Study Program, Al-Manan NU Islamic Institute, East Lombok, East Lombok, Indonesia.

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Correspondence:

Rabiatul Hasanah

Phone: +6287882075881

Abstract: This study aims to develop a Socio-Scientific Issues (SSI)-based Student Worksheet (Lembar Kerja Peserta Didik, LKPD) on climate change material and evaluate its practicality and effectiveness on students' scientific attitudes. This research is development research with a 4D model that includes the define, design, develop, and disseminate stages. However, this article focuses on the development stage, especially the results of the practicality test and effectiveness test. The research subjects were grade X students of MAS Al-Chalil. The developed product has passed expert validity testing using Aiken's V index and obtained a value of more than 0.80, so it is declared valid and worthy of being tested. Practicality data were obtained through learning implementation sheets, teacher response questionnaires, and student response questionnaires, while effectiveness data were obtained through scientific attitude questionnaires given before and after learning. The results showed that the learning implementation obtained an average of 92%, teacher response of 91.25%, and student response of 89.08%, so the SSI-based Student Worksheet is included in the practical category. The results of the effectiveness test indicated that the average pretest score for students' scientific attitudes increased from 49.60 to 74.20 in the posttest, with an N-Gain value of 69.49%, which is categorized as moderate and interpreted as quite effective. The highest increase was in the sensitivity in investigating the environment indicator at 84.38%, while the lowest increase was in the curiosity indicator at 51.22%. Thus, the SSI-based LKPD on climate change material is practical and quite effective for improving students' scientific attitudes.

Keywords: Climate Change; Effectiveness; LKPD; Practicality; Scientific Attitude; Socio-Scientific Issues.

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Introduction

Climate change is a global environmental issue with far-reaching impacts on human life, ecosystems, health, water availability, food security, and sustainable development. Scientific evidence indicates that the Earth is warming at an unprecedented rate, and human activity is the primary cause of this global warming (Intergovernmental Panel on Climate Change, 2023; NASA Science, 2024). The impacts of climate change are not only evident in the increase in the Earth's average temperature but also in the increase in extreme weather events, changes in rainfall patterns, droughts, floods, sea level rise, ecosystem damage, and increased socio-economic vulnerability (Intergovernmental Panel on Climate Change, 2023; Kolenatý et al., 2022). Therefore, climate change needs to be understood not simply as a

Email: rabyatul267@gmail.com

scientific concept but as a multidimensional issue related to social, economic, environmental, health, technological, and ethical aspects of life. NASA asserts that the evidence for global warming is unequivocal and that human activity is the primary cause, while the Intergovernmental Panel on Climate Change (IPCC) summarized the impacts and risks of climate change broadly in its AR6 Synthesis Report. Referring to the current conditions resulting from climate change, particularly in the Lombok region, the weather is unpredictable, even between nearby areas, such as villages. In one village, it's hot today, but rain falls in the village across the street a short time later. This is certainly a tangible impact, in addition to the rising average temperature in the Lombok region of West Nusa Tenggara. The unpredictable seasons directly impact the surrounding community, particularly those involved in agriculture. It also impacts general community activities when planning long-distance travel.

Education plays a strategic role in equipping students to understand, analyze, and make scientific decisions on climate change issues. UNESCO emphasizes that climate change education is not simply about transferring knowledge but rather about social-emotional, reflective, and action-oriented learning (UNESCO, 2024a). Similarly, the PISA 2025 framework places students' ability to understand environmental issues as part of agency in the Anthropocene, namely, the ability to explain the impact of human interactions on the earth system, evaluate various evidence, make decisions, and act responsibly in the face of socio-ecological crises (OECD, 2025; Nurhayati et al., 2020; White et al., 2023). Therefore, science learning in schools, including physics, needs to be designed to connect scientific concepts with real-world problems relevant to students' lives (Rizaldi et al., 2021; Rizaldi & Fatimah, 2023). UNESCO also targets more countries to include climate change in the curriculum, while PISA 2025 emphasizes environmental competencies, use of evidence, and decision-making in science (UNESCO, 2024b).

In physics lessons, climate change is closely linked to the concepts of energy, solar radiation, the greenhouse effect, heat transfer, Earth's energy balance, global warming, and their impacts on life. However, climate change instruction in schools is often largely informative and teacher-centered, resulting in students primarily receiving concepts rather than engaging in the activities of analyzing data, interpreting evidence, comparing arguments, and formulating solutions. In fact, climate change instruction should provide students with the opportunity to develop conceptual understanding as well as scientific attitudes, such as curiosity, objectivity, openness to evidence, scientific honesty, responsibility, and concern for the environment (Sakliressy et al., 2021; Syah, 2023; Tang, 2024). Based on observations of learning at MAS Al-Chalil, it is clear that innovation in the learning process is necessary, especially when studying the concept of environmental change. Learning generally utilizes various supporting media such as LCD projectors or interactive videos. This utilization certainly provides better opportunities compared to one-way learning, known as teacher-centered learning. However, given the study's focus on climate change, students require concrete and contextual steps to cultivate scientific attitudes. One way teachers can do this is by having students directly observe the process of environmental change and its impact on the environment around them. Providing direct instructions will certainly foster awareness in students about the importance of preserving the environment to prevent the potential for accelerated environmental change.

Scientific attitudes are crucial because science instruction aims not only to produce students who understand concepts but also students who are able to think based on data, be critical of information, and make rational decisions. One relevant approach to presenting climate change learning contextually is Socio-Scientific Issues (SSI) (Ahmad et al., 2024; Arifin et al., 2024; Arifin et al., 2025). SSI is a learning approach that raises social issues that are scientifically based, complex, open to debate, and related to real-life decision-making. Through SSI, students not only learn scientific concepts but are also encouraged to understand the relationships between science, technology, society, the environment, and human values (Karisan & Zeidler, 2017; Sadler et al., 2016; Yacoubian & Khishfe, 2018). The SSI approach provides students with opportunities to read phenomena, identify problems, examine scientific evidence, discuss, build arguments, evaluate impacts, and determine attitudes toward an issue. Recent systematic reviews indicate that SSI learning is widely used to develop students' understanding of scientific concepts, scientific literacy, argumentation, decision-making, and higher-order thinking skills (Högström et al., 2025; Kumar et al., 2024; Nielsen, 2020; Sari et al., 2025). Högström et al.'s (2025) systematic review indicates that SSI is largely directed at strengthening scientific knowledge and higher-order thinking skills, while Kumar et al. place climate change as one of the primary contexts for environmental SSI.

The SSI approach is highly appropriate for climate change because the issue is current, controversial, multidisciplinary, and has a direct impact on people's lives. Climate change allows students to learn scientific concepts through real-world examples, such as rising temperatures, floods, droughts, energy consumption, fossil fuel use, carbon emissions, changing seasonal patterns, and environmental impacts on their surroundings. SSI-based learning can also encourage

students to connect scientific data with the social, economic, cultural, and ethical dimensions of an issue (Hancock et al., 2019; Herman, 2018; Herman et al., 2020). Furthermore, the use of environmental issues in SSI can strengthen scientific literacy, modeling skills, environmental awareness, and students' readiness to make decisions based on scientific evidence (Ke et al., 2021; Kinskey & Zeidler, 2021; Susilawati et al., 2021; Zangori et al., 2017).

While SSI has great potential, its implementation requires learning tools that can systematically guide student activities. One such tool is the Student Worksheet (*Lembar Kerja Peserta Didik,* LKPD). LKPD serves as teaching materials containing activity instructions, problem stimuli, supporting information, guiding questions, analytical activities, discussion activities, reflection, and assessment. Well-designed LKPD can help students learn more actively, independently, collaboratively, and in a focused manner (Raudoh, 2023). In the context of SSI, student worksheets (LKPD) can be designed to include climate change cases, scientific data or discourse, analytical questions, argumentative activities, value reflection, and decision-making activities. Therefore, SSI-based LKPDs have the potential to become learning tools that not only help students understand climate change material but also cultivate scientific attitudes through evidence-based activities and real-world issues.

Several previous studies have shown that SSI-based teaching materials are effective in science learning. Ameliawati et al. (2021) developed an SSI-based student worksheet (LKPD) on climate change and demonstrated its suitability for use in science learning. Putri et al. (2023) found that SSI-based teaching materials on climate change are needed to improve students' decision-making skills. Utami et al. (2023) developed an SSI-based global warming e-module to improve critical thinking skills and sustainability awareness. Lestari et al. (2025) developed a PBL-SSI e-module on climate change to support sustainability awareness and interdisciplinary thinking skills.

Usamah et al. (2025) showed that the SSI-based climate change e-module has good validity and practicality, while Usamah et al. (2026) reported that the SSI-based climate change e-module effectively improves students' problem-solving skills and environmental literacy. These results indicate that SSI is relevant for use as a basis for developing climate change teaching materials. A recent study on SSI-based climate change e-modules also demonstrated a strong need for digital learning resources that connect scientific concepts to real-world environmental issues, as well as significant improvements in experimental classes following the use of SSI e-modules. In addition to climate change material, the development of SSI-based student worksheets (LKPD) or teaching materials has also been shown to support various students' scientific abilities. Fajarani et al. (2025) developed SSI-based LKPDs to facilitate students' written argumentation skills. Ulliva & Prodjosantoso (2025) developed SSI-based LKPDs and tested their impact on students' chemical literacy and scientific attitudes. Anggianti et al. (2026) demonstrated that SSI-based student worksheets in chemistry labs achieved high validity and positive responses from both teachers and students. Qalfin et al. (2024) reported that differentiated digital SSI-based LKPDs effectively improved students' scientific literacy. Chomsun et al. (2024) also confirmed that the development of SSI-based e-LKPDs can be a means of building scientific literacy. These findings reinforce the potential for SSI-based student worksheets (LKPD) to be used as practical, contextual, and meaningful learning tools.

However, studies specifically examining the practicality and effectiveness of SSI-based LKPD on climate change require further research. Most previous research has focused on scientific literacy, critical thinking skills, argumentation, problem-solving, or environmental awareness. Meanwhile, scientific attitudes, as a key outcome of science learning, require further in-depth study, particularly in the context of physics instruction at the high school level. Scientific attitudes are crucial because they relate to students' readiness to ask questions, seek evidence, think objectively, value data, be open to arguments, and take responsibility for making scientific decisions (Putri & Aznam, 2024; Sakliressy et al., 2021; Sugrah et al., 2023; Syah, 2023). Therefore, the development of SSI-based LKPD on climate change needs to be evaluated from two main aspects: practicality and effectiveness. Practicality indicates the extent to which a worksheet is easy for teachers and students to use, has clear instructions, fits the time allocation, is engaging, and supports learning activities. Effectiveness indicates the extent to which the worksheet impacts students' scientific attitudes.

Based on this description, research on the Development of Socio-Scientific Issues (SSI)-Based Worksheets for Climate Change: Evaluation of Practicality and Effectiveness on Students' Scientific Attitudes is important. This research is expected to produce worksheets that are not only suitable for use but also practical to implement in learning and effective in fostering students' scientific attitudes. Theoretically, this research can enrich studies on the development of SSI-based teaching materials in physics. Practically, the results of this study can serve as an alternative learning tool for teachers in teaching climate change in a contextual manner, based on real issues, and oriented towards developing students' scientific attitudes.

Method

Research Design

This research is a research and development (R&D) project aimed at producing a Socio-Scientific Issues (SSI)-based worksheet on climate change and evaluating its practicality and effectiveness on students' scientific attitudes. The development model used is a 4D design, which includes four stages: Define, Design, Develop, and Disseminate. The Define stage analyzes learning needs, student characteristics, material characteristics, and climate change learning challenges. The design stage designs the worksheet structure, SSI-based activity syntax, scientific attitude indicators, presentation format, and research instruments. The development stage involves expert validation, product revision, practicality testing, and effectiveness testing. The disseminate stage focuses on limited product dissemination.

This research specifically focuses on the results of the Develop stage, which tests the practicality and effectiveness of the SSI-based worksheet. Prior to the trial, the worksheet and learning support materials underwent expert validation. The validity of the Student Worksheets (LKPD) is appraised across four principal validity dimensions: content validity, construct validity, linguistic validity, and visual-design validity. Content validity concerns the alignment of the material with the curriculum, the stated learning objectives, and the accuracy of the concepts conveyed. Construct validity appraises the coherence among LKPD components, including instruction clarity, orderly organization, and the concordance of activities with the chosen instructional model or pedagogical approach. Linguistic validity encompasses the deployment of communicative language that is appropriate to learners' developmental level and conforms to established language norms. Meanwhile, visual-design validity evaluates aspects of layout design, tidiness, legibility of typography, the use of imagery and color, and overall arrangement to ensure the LKPD is aesthetically engaging and readily usable by students.

The validation results were analyzed using Aiken's V index and obtained a validity value of more than 0.80, thus declaring the LKPD and learning tools valid and suitable for use in the trial phase. Therefore, the trial in this study was conducted after the product met the content and construct validity criteria.

Research Subjects and Locations

The research was conducted at MAS Al-Chalil on tenth-grade students studying climate change. The subjects consisted of tenth-grade students as users of the worksheets, subject teachers as practicing users, and observers who assessed the effectiveness of the learning. Subjects were selected using purposive sampling, based on the consideration that students were at a level and with material relevant to the developed SSI-based worksheets. The practicality test involved tenth-grade students as respondents, teachers as device users, and observers as assessors of the effectiveness of the learning. The effectiveness test was conducted in a pilot class using a one-group pretest-posttest design. Students were given a scientific attitude questionnaire before the lesson, then participated in learning using the SSI-based worksheets, and then received a scientific attitude questionnaire after the lesson.

Practicality Test

Procedure for Implementing the Practicality Test

The practicality test was conducted after the SSI-based worksheets and learning tools were declared valid based on expert validation. The practicality test aimed to obtain data on ease of use, implementation, readability, appeal, content suitability, and teacher and student responses to the SSI-based worksheets on climate change. The practicality test was conducted using a quantitative descriptive method. Learning was conducted using the SSI-based worksheets, which included climate change issues, contextual problem stimuli, guiding questions, scientific evidence analysis activities, discussions, reflections, and decision-making. During the learning process, observers completed a learning implementation sheet. After the learning activity was completed, teachers and students completed a response questionnaire to assess the practicality of the worksheets.

Practicality Test Data Collection Techniques

The data collection technique for the practicality test used three instruments: a learning implementation sheet, a teacher response questionnaire, and a student response questionnaire. The student response questionnaire was scored on a Likert scale of 1 to 5: very poor, poor, sufficient, good, and very good. Student responses are one of the main indicators for determining whether the SSI-based LKPD is practical for use in learning.

Practicality Test Data Analysis Techniques

The data from the learning implementation sheet, teacher response questionnaire, and student response questionnaire were analyzed descriptively quantitatively using the following percentage formula.

$$\mathbf{P_{(k)} = \frac{S}{N} \ x\ 100\ \%}$$

Information:

$P_{(k)}$	=	Percentage of components
S	=	Total score obtained
N	=	Maximum score

After being analyzed, the results of the learning implementation questionnaire, teacher responses, and

student responses were then interpreted based on the practicality criteria in Table 1.

Table 1. Practicality Criteria

Practicality Percentage (%)	Level of Practicality
75.01 – 100.00	Practical
50.01 – 75.00	Quite practical
25.01 – 50.00	Less practical
≤ 25.00	Not practical

(Source: Marisa *et al*., 2020)

Effectiveness Test

Procedure for Implementing Effectiveness Tests

An effectiveness test was conducted to determine the ability of SSI-based student worksheets (LKPD) to improve students' scientific attitudes on climate change. The effectiveness test was conducted using an experimental method with a one-group pretest-posttest design. This design was used because the study focused on comparing students' scientific attitudes before and after learning using SSI-based LKPD. The effectiveness test design is presented in Table 2.

Table 2. Effectiveness Test Design

Group	*Pretest*	*Treatment*	*Posttest*
E	O_1	T	O_2

Information:

E : Experimental class
O_1 : Pretest
T : Learning using SSI-based LKPD
O_2 : Posttest

Effectiveness Test Data Collection Techniques

The data collection technique for the effectiveness test used a non-test technique in the form of a scientific attitude questionnaire. This questionnaire was used to measure students' scientific attitudes before and after learning using SSI-based LKPD. The scientific attitude questionnaire was compiled based on several indicators, namely: Curiosity, respect for evidence, flexibility in ways of thinking, critical reflection, and sensitivity in investigating the environment.

Effectiveness Test Data Analysis Techniques

The effectiveness of SSI-based student worksheets was analyzed using the N-gain score. N-gain analysis was used to determine the improvement in students' scientific attitudes between before and after learning. The N-gain formula used is as follows.

$$N\text{-}gain\ (g) = \frac{S_{post} - S_{pre}}{S_{max} - S_{pre}} \times 100\%$$

Information:

N-gain : gain score
S_{post} : posttest scores
S_{pre} : pretest score
S_{maks} : ideal maximum score

The results of the N-gain calculation are then categorized based on the following criteria.

Table 3. N-Gain Obtaining Criteria

Interval	Criteria
$g > 0.7$	High
$0.3 \leq g \leq 0.7$	Medium
$g < 0.3$	Low

(Source: Hake,1998)

Table 4. Interpretation of the effectiveness of the N-Gain standard

Percentage (%)	Category
< 40	Ineffective
40 - 55	Less effective
56 - 75	Quite effective
> 76	Effective

(Source: Taufik & Doyan, 2022)

Result and Discussion

The results and discussion of this study present the findings of a trial of Socio-Scientific Issues (SSI)-based LKPD on climate change material, which focuses on the practicality and effectiveness aspects of students' scientific attitudes.

Practicality Test Results

A practicality test was conducted to determine the extent to which the Socio-Scientific Issues (SSI)-based student worksheets on climate change can be used easily, engagingly, and appropriately for classroom learning needs. Practicality data was obtained through learning implementation sheets, teacher response questionnaires, and student response questionnaires after the LKPD was implemented.

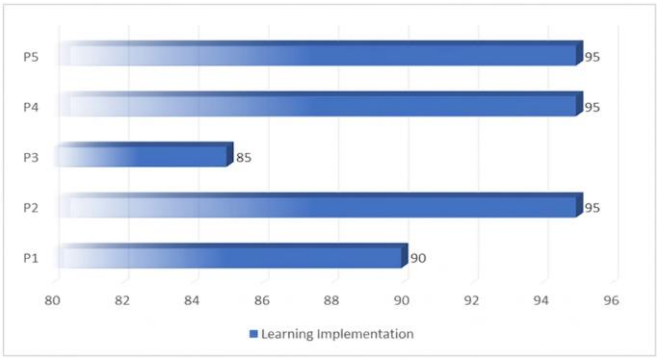

Figure 1. Learning Implementation Results

Information
P : Learning Meeting

Based on Figure 1, the implementation of learning using Socio-Scientific Issues (SSI)-based worksheets on climate change demonstrated excellent results at each meeting. The learning implementation percentage for P1 was 90%, P2 95%, P3 85%, P4 95%, and P5 95%, with an average implementation rate of 92%. These results indicate that all stages of the SSI-based learning were implemented well by teachers and optimally followed by students. Although the implementation rate for P3 received the lowest score, at 85%, it still falls within the practical category. The decrease in percentages in the third meeting was due to several students not participating in the assessment process, which impacted the overall accumulated percentage score. This will certainly serve as a future evaluation for researchers in conditioning the research data to produce optimal results. Furthermore, the sub-topics taught in the third meeting were more difficult to analyze than in the previous meeting, so students perceived the need for more than one face-to-face meeting to maximize their understanding of the material before the assessment process at the end of the meeting. Therefore, the developed SSI-based worksheets can be considered practical for use in learning, as all implementation scores ranged from 75.01 to 100%.

The high implementation rate indicates that the SSI-based worksheets have a clear, systematic, and easy-to-implement activity structure in the learning process. This indicates that the learning syntax in the Student Worksheet (LKPD), starting from the presentation of climate change issues, problem identification, scientific information analysis, group discussions, argumentation, and reflection on scientific attitudes, can be implemented according to the learning design. This finding aligns with Sadler et al. (2016), who explained that SSI-based learning can support student engagement in understanding science content through the context of real-life issues relevant to life. Furthermore, the SSI approach also allows students to connect scientific concepts with social and environmental issues, making learning more meaningful and contextual (Hancock et al., 2019; Kumar et al., 2024). In the context of this research, the issue of climate change is a relevant learning context because it is directly related to students' lives and allows students to develop curiosity, concern for evidence, and critical thinking skills.

The average learning success rate of 92% also demonstrates that the SSI-based Student Worksheet (LKPD) meets the practicality criteria in terms of ease of use in the classroom. Practicality of the LKPD is demonstrated not only by the appearance or readability of the teaching materials but also by the tool's ability to guide teachers and students in conducting directed learning. These results are supported by research by Ameliawati et al. (2021), which demonstrated that the SSI-based LKPD on climate change is suitable for use in learning because it presents contextual issues relevant to students' lives. Similarly, Putri et al. (2023) emphasized that SSI-based teaching materials on climate change are needed to help students understand environmental issues and develop scientifically informed decision-making skills. Therefore, the high learning success rate in this study confirms that the SSI-based LKPD can be used as an applicable, contextual, and appropriate learning tool for science learning. The 85% decrease in the percentage in P3 can be interpreted as part of the dynamics of socio-scientific issue-based learning, which requires students to be more active in analyzing information, discussing, and developing evidence-based reasoning. At this stage, students likely need more time to adjust to learning activities that require argumentation, reflection, and decision-making. However, the 95% increase in P4 and P5 indicates that students and teachers are becoming accustomed to the SSI-based learning pattern. This aligns with research by Herman et al. (2020), which states that SSI learning involves reasoning, emotions, values, and social considerations, thus requiring familiarity. Research by Ke et al. (2021) also shows that the use of SSI can help students develop scientific literacy through modeling activities, the use of evidence, and discussions on real-world problems.

Overall, the results of the learning implementation indicate that the SSI-based Student Worksheet (LKPD) on climate change is categorized as practical and can be used in 10th-grade physics lessons. This finding aligns with research by Usamah et al. (2025), which showed that SSI-based climate change teaching materials have a good level of practicality because they are able to facilitate contextual learning and encourage student engagement. Furthermore, Ulliva & Prodjosantoso (2025) also reported that SSI-based student worksheets can have a positive influence on students' chemical literacy and scientific attitudes. Thus, the high learning implementation in this study is the basis for SSI-based student worksheets not only being practical to use but also having the potential to support the achievement of learning objectives, particularly in fostering students' scientific attitudes through learning based on real issues, scientific evidence, discussion, and reflection.

Based on Figure 2, teacher responses to the developed learning tools showed excellent results across all assessment aspects. The teaching module scored 92.5%, the learning materials scored 90%, the SSI-based Student Worksheet (LKPD) scored 87.5%, and the scientific attitudes questionnaire scored the highest at 95%. The average teacher response reached 91.25%, placing it in the practical category. These results indicate that the learning tools, particularly the Socio-Scientific Issues (SSI)-based Student Worksheet (LKPD), were

deemed easy to use, appropriate for the climate change material, supportive of learning implementation, and relevant for measuring students' scientific attitudes.

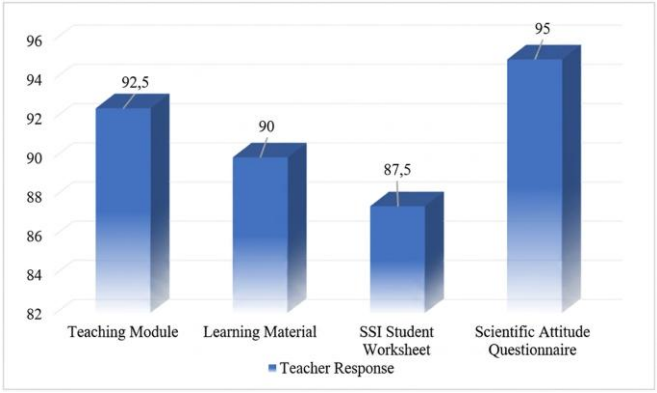

Figure 2. Teacher Response Results

Teacher responses in the practical category indicate that the SSI-based Student Worksheet on climate change material has good usability in learning. The highest score was found in the scientific attitudes questionnaire, at 95%, indicating that the instrument used was deemed appropriate for measuring indicators of students' scientific attitudes, such as curiosity, appreciation of evidence, flexibility of thinking, critical reflection, and sensitivity to the environment. These findings align with Sugrah et al. (2023), who emphasized that SSI-based learning can foster scientific attitudes because students are guided to analyze real-life issues through critical thinking, reflection, and evidence-based reasoning. Furthermore, Putri and Aznam (2024) also demonstrated that students' scientific attitudes can be strengthened through learning that presents contextual problems and demands active student involvement in the investigation process.

Teacher response scores of 92.5% for the teaching module and 90% for the learning materials indicate that the developed tools are appropriate for classroom learning needs. Climate change material has characteristics relevant to the SSI approach because it addresses environmental issues close to students' lives and can be examined from both scientific and social perspectives. Subiantoro and Treagust (2021) explained that SSI-based learning requires tools that can connect scientific concepts with real-life issues so students can understand the issues more meaningfully. This is also supported by Chomsun et al. (2024), who stated that the development of SSI-based e-LKPD can help build scientific literacy because students are involved in the process of understanding issues, analyzing information, and connecting scientific concepts to everyday life contexts.

The SSI-based Student Worksheet (LKPD) aspect scored 87.5%, which, although the lowest compared to other aspects, still falls into the practical category. This indicates that teachers assess the LKPD as usable in learning but still have room for improvement, for example, in the clarity of instructions, the timing of discussions, or adjusting the difficulty level of student activities. Fajarani et al. (2025) emphasized that SSI-based student worksheets need to be systematically designed to facilitate students in developing arguments based on data and evidence. Similarly, Qalfin et al. (2024) demonstrated that SSI-based student worksheets designed to suit student characteristics can increase student engagement and support the strengthening of scientific literacy. Thus, the teacher responses indicate that the developed LKPD is practical to use, but attention to the clarity of activities and appropriate timing remains necessary.

Overall, the average teacher response rate of 91.25% reinforces the high level of practicality of the developed learning tools. This practicality demonstrates that SSI-based student worksheets are not only theoretically feasible but can also be applied by teachers in real-life learning situations. Raudoh (2023) stated that good student worksheets (LKPD) need to help students learn actively, in a focused, and independent manner through clear activity instructions. Furthermore, Anggianti et al. (2026) demonstrated that SSI-based student worksheets received positive responses from users because they were able to present contextual and relevant learning activities for science learning. Therefore, the high teacher response in this study is evidence that SSI-based LKPD on climate change material is practically used to support learning oriented towards strengthening students' scientific attitudes.

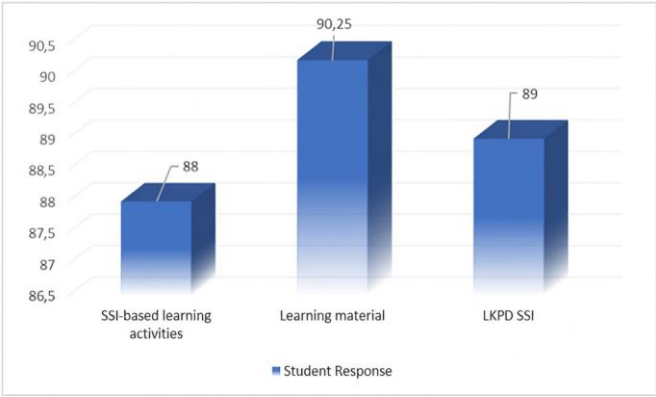

Figure 3. Student Response Results

Based on Figure 3, student responses to the use of Socio-Scientific Issues (SSI)-based worksheets (LKPD) on climate change demonstrated excellent results. The SSI-based learning activities aspect scored 88%, the learning materials received the highest score of 90.25%, and the SSI LKPD scored 89%. The average student response was 89.08%, making it categorized as practical. These results

indicate that students responded positively to the developed learning, both in terms of interest in climate change issues, ease of understanding the material, and the use of the LKPD as a learning guide.

The high student response to the learning materials aspect (90.25%) indicates that the climate change material was considered interesting, relevant, and easily related to everyday life. Climate change material does have contextual characteristics because it relates to real-world phenomena such as rising temperatures, weather changes, floods, droughts, carbon emissions, and the impact of human activities on the environment. This is in line with Kolenatý et al. (2022), who stated that climate change education can improve climate literacy and students' willingness to take action when presented through meaningful learning that is relevant to their lives. Therefore, the high student response to the material demonstrates that climate change issues can provide an engaging and relevant learning context in physics.

The SSI Student Worksheet (LKPD) aspect received a score of 89%, indicating that the LKPD is considered to assist students in following the learning process. SSI-based LKPD functions not only as a worksheet but also as an activity guide that guides students in reading issues, identifying problems, analyzing scientific information, discussing, and making decisions based on evidence. Li & Guo (2021) emphasized that science learning involving socio-scientific issues can help students develop scientific literacy because they learn to connect scientific information with public issues. Furthermore, Zangori et al. (2017) demonstrated that SSI-based climate change learning can help students develop scientific reasoning through modeling and analyzing carbon and climate phenomena. Therefore, the positive student response to the SSI Student Worksheet indicates that the developed tool is capable of facilitating active, contextual, and evidence-based learning.

The 88% score for the SSI-based learning activities aspect indicates that students were able to participate effectively in the learning activities, although this aspect had the lowest score compared to the other aspects. This is understandable because SSI-based learning requires students to be more active in discussions, expressing opinions, analyzing evidence, and considering multiple perspectives before making decisions. According to Yacoubian and Khishfe (2018), SSI learning involves argumentation, critical thinking, understanding the nature of science, and decision-making, thus requiring higher cognitive engagement. Karisan and Zeidler (2017) also explained that SSI provides students with a space to understand science contextually through issues related to society and real life. Therefore, although the SSI activities were challenging, students' responses remained high, indicating that the learning was well-received. Overall, the average student response of 89.08% confirms that the SSI-based worksheet on climate change is practical for use in learning. These positive responses indicate that students felt helped in understanding the material, were more interested in participating in the learning, and gained a more meaningful learning experience through socio-scientific issues.

Nielsen (2020) stated that SSI in science education can strengthen learning because students not only understand concepts but also learn to consider the social, ethical, and environmental aspects of a scientific problem. Similarly, Tang (2024) emphasized that climate change education in Indonesia needs to be directed towards more contextual learning so that students can understand environmental issues as part of life and social responsibility. Thus, the results of student responses indicate that SSI-based student worksheets are not only practical to use but also have the potential to support more active, relevant physics learning and are oriented towards strengthening students' scientific attitudes.

Effectiveness Test Results

An effectiveness test was conducted to determine the improvement in students' scientific attitudes after using Socio-Scientific Issues (SSI)-based student worksheets on climate change. Effectiveness data were obtained through a scientific attitude questionnaire administered before and after learning (pretest).

Table 5. Average Results of Effectiveness Test

Component	Average value
Pretest	49.60
Posttest	74.20
N-Gain	69.49%

Table 6. N-Gain Per Indicator

No.	Attitude Indicators	N-Gain (%)	N-Gain Category	Interpretation of Effectiveness
1	*curiosity*	51.22	Medium	Less effective
2	*respect for evidence*	63.64	Medium	Quite effective
3	*flexibility in ways of thinking*	71.43	High	Quite effective
4	*critical reflection*	82.35	High	Effective
5	*sensitivity in investigating the environment*	84.38	High	Effective

Overall average	**69.49**	Medium	**Quite effective**

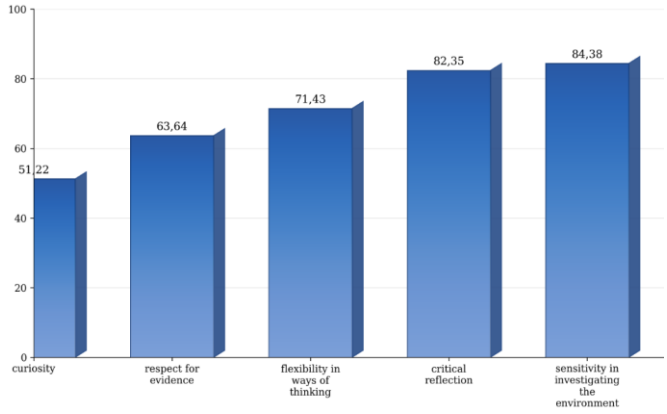

Figure 4. Comparison of N-gain Results for Each Indicator

Based on Table 5, the effectiveness test results show that the average pretest score for students' scientific attitudes was 49.60, which then increased to 74.20 in the posttest after learning using Socio-Scientific Issues (SSI)-based worksheets. This increase resulted in an N-Gain value of 69.49%, which is in the moderate category and interpreted as quite effective. These results indicate that SSI-based worksheets on climate change are able to improve students' scientific attitudes, although their effectiveness level is not yet fully effective. Therefore, the developed worksheets can be considered quite effective for use in teaching physics in grade 10 of MAS Al-Chalil.

The increase in the average score from 49.60 to 74.20 indicates that learning using SSI-based worksheets has a positive impact on the development of students' scientific attitudes. This is possible because SSI-based worksheets present climate change material in the form of real-life issues relevant to students' lives, such as rising temperatures, weather changes, floods, droughts, and the impact of human activity on the environment. SSI-based learning encourages students not only to understand scientific concepts but also to connect those concepts to social and environmental issues and evidence-based decision-making. These findings align with Kumar et al. (2024), who stated that SSI-based environmental issues can be an important context for developing scientific literacy and students' ability to understand real-world problems. Furthermore, Nielsen (2020) emphasized that SSI in science education helps students connect scientific knowledge with the social, ethical, and responsibility dimensions of everyday life.

Based on indicators, the highest improvement was seen in the sensitivity in investigating the environment indicator with an N-gain of 84.38% and the critical reflection indicator with 82.35%, both of which are within the effective range. This indicates that SSI-based student worksheets (LKPD) significantly support students in becoming more sensitive to environmental phenomena and more able to critically reflect on climate change issues. The activities in the LKPD, which include climate change issue analysis, group discussions, information review, and reflection on environmental impacts, provide opportunities for students to develop scientific awareness of the problems occurring around them. These results align with Herman (2018), who demonstrated that learning based on environmental socio-scientific issues can strengthen students' awareness, intention to act, and engagement with environmental issues. Susilawati et al. (2021) also emphasized that SSI can be a means to increase students' environmental awareness and social skills in science learning.

The flexibility in ways of thinking indicator achieved an N-Gain of 71.43%, categorized as high improvement, but its effectiveness was still considered moderately effective. These results indicate that students are beginning to be able to consider multiple perspectives in understanding climate change issues, although this ability still requires further development. In SSI learning, students are confronted with complex and open-ended issues, requiring them to consider scientific information, social values, environmental impacts, and possible solutions. According to Yacoubian and Khishfe (2018), SSI learning requires students to use argumentation, think critically, and understand the nature of science in assessing a problem. Therefore, the improvement in the flexibility of thinking indicator indicates that the SSI-based worksheet has provided space for students to develop more open-minded ways of thinking, although it has not yet achieved maximum effectiveness.

Meanwhile, the respect for evidence indicator achieved an N-Gain of 63.64%, considered moderately effective, while the curiosity indicator achieved the lowest N-Gain, at 51.22%, considered moderately effective. These results indicate that although students are beginning to show improvement in their appreciation of evidence and curiosity, both aspects still require reinforcement in the learning process. The low improvement in the curiosity indicator may be due to students not yet being fully accustomed to asking questions, seeking additional information, or exploring issues independently. In fact, SSI learning ideally encourages students to actively ask questions, explore evidence, and build understanding based on data. Ke et al. (2021) explain that SSI learning can strengthen scientific literacy if students are actively involved in using evidence, modeling, and reasoning on real-world

issues. Therefore, in subsequent implementations, LKPD needs to be strengthened with trigger questions, data exploration activities, and investigative tasks that further stimulate students' curiosity.

Overall, the average N-Gain of 69.49% indicates that the SSI-based Student Worksheet (LKPD) is considered quite effective in improving students' scientific attitudes. These results demonstrate that the developed LKPD has been able to facilitate contextual, issue-based learning and encourage students to think reflectively about climate change issues. However, the lack of overall effectiveness indicates that improvements are still needed in several aspects, particularly activities that can foster students' curiosity and habits in using scientific evidence. This finding aligns with Ulliva & Prodjosantoso (2025), who demonstrated that SSI-based student worksheets can influence students' scientific literacy and attitudes, but their success is highly dependent on the quality of the activity design, student engagement, and the continued adoption of scientific thinking habits in learning.

Thus, the effectiveness test results indicate that the Socio-Scientific Issues-based Student Worksheet on climate change is quite effective in improving the scientific attitudes of 10th-grade students at MAS Al-Chalil. This LKPD provides the strongest contribution to the indicators of critical reflection and environmental sensitivity, while the indicators of curiosity and appreciation for evidence still need to be improved through the design of learning activities that are more exploratory, data-based, and challenge students to ask questions and investigate climate change issues in more depth.

Conclusion

Based on the research results, the Socio-Scientific Issues (SSI)-based Student Worksheet (LKPD) on climate change material was declared practical and quite effective for use in physics learning for Class X MAS Al-Chalil. The practicality of the LKPD was demonstrated through the implementation of learning of 92%, teacher responses of 91.25%, and student responses of 89.08%, all of which were in the practical category. The results of the effectiveness test showed that the average score of students' scientific attitudes increased from 49.60 in the pretest to 74.20 in the posttest, with an N-Gain value of 69.49%, which was included in the moderate category and interpreted as quite effective. Thus, the SSI-based Student Worksheet was quite effective in improving students' scientific attitudes, especially in the aspects of critical reflection and sensitivity to the environment.

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