

---

## **Developing Global Warming Module Based on Education for Sustainable Development to Increase Middle School Students' Understanding and Sustainability Awareness**

**Senda Tiara Putri<sup>1</sup>, Indra Fardhani<sup>1\*</sup>, Yayuk Mulyati<sup>1</sup>, Bakhrul Rizky Kurniawan<sup>2</sup>, Adella Anfidina Putri<sup>3</sup>**

<sup>1</sup>Departement of Science Education, State University of Malang, East Java, Indonesia

<sup>2</sup>Departement of Physics, State University of Malang, East Jawa, Indonesia

<sup>3</sup>Department of Social and Human Environment, GSES, Nagoya University, Japan

\*Email: [indra.fardhani.fmipa@um.ac.id](mailto:indra.fardhani.fmipa@um.ac.id)

---

### **Article History:**

Received date: August 15 2024

Received in revised from: December 4 2024

Accepted date: March 8 2024

Available online: April 8 2024

### **Citation:**

Putri, S.T., Fardhani, I., Mulyati, Y., Kurniawan, B.R., & Putri, A.A. 2024. Developing global warming module based on education for sustainable development to increase middle school students' understanding and sustainability awareness. *Jurnal Pendidikan Sains Indonesia (Indonesian Journal of Science Education)*, 12(2):247-263

### **Abstract.**

The environmental crisis, which is a global problem, can be overcome by increasing sustainability awareness. The education for sustainable development (ESD) based global warming module can increase understanding and sustainability awareness. The goal of this research was to create a module based on ESD that deserves to be tested for its effectiveness in raising junior high school student's understanding and sustainability awareness of global warming. The development procedure is based on the ADDIE model (analyze, design, develop, implement, and evaluate) data collection techniques using interviews, questionnaires, and pretest-posttest questions. The data analysis techniques used are the descriptive qualitative technique, percentage analysis, readability test, validity and reliability test, normality and homogeneity test, independent sample t-test, N-gain test, and effect size test. The results of media and material validation tests show very valid criteria. The results of the N-gain test in the post-test control class showed low criteria, while those in the experimental class showed medium bars. The outcomes of the effect size test in the post-test control and practical classes show high criteria. This research indicates that the modules developed are valid and effective for increasing students' understanding and sustainability awareness.

**Keywords:** Sustainable development, module, understanding, sustainability awareness, global warming.

---

## **Introduction**

The environmental crisis shows that there is something wrong with today's human lifestyle and indicates that the balance of the ecosystem has been disturbed (Marianta, 2011). Climate change due to global warming has also worsened the quality of the environment today, where environmental damage has reached a worldwide level and is still growing (Sukananda & Nugraha, 2020). The ecological crisis can be resolved by increasing awareness about environmental problems, where one of the proper steps that can be taken is to strengthen environment-based education in primary and secondary schools (Ntanos *et al.*, 2018; Ergin, 2019; Ekamilasari & Pursitasari, 2021). Environmental awareness as part of character education must be addressed by schools (Wihardjo *et al.*, 2017; Wangid, 2018). Nevertheless, the empirical evidence indicates that students are less

encouraged to take action to care for the environment because of the absence of education specifically targeting sustainable development practices within schools. (Suwanto *et al.*, 2021; Rahmah, 2022).

Sustainable development aims to improve the standard of living of the world community to meeting the requirements of the present generation without diminishing the ability or skills of future generations to fulfill their own needs (Segara, 2015; UNESCO, 2017; Nursadiyah *et al.*, 2018). In line with this explanation, the word sustainable is defined as a concept in human life that utilizes limited resources by maintaining balance in the economic, social, and environmental fields (Klarin, 2018; Novidsa *et al.*, 2020). Education for Sustainable Development (ESD) provides students with insights, skills, values, and behaviors in analyzing, making, and deciding actions that care for the well-being of the environment, ongoing economic stability, and social equity for both present and future generations (Brundiers & Wiek, 2013; Kalsoom & Khanam, 2017; UNESCO, 2017; Rahman *et al.*, 2019; Novidsa *et al.*, 2020; Purnamasari & Hanifah, 2021; Simbolon, 2021).

In learning process, ESD ushers in a paradigm shift, moving away from solely knowledge transfer (teacher-centered) and towards action-oriented, student-driven learning. This approach emphasizes transformative learning, where knowledge is not merely acquired but actively reconstructed and applied to real-world challenges. As a result, students are expected to both gain knowledge and improve their awareness, behavior, and actions (Japan National Commission for UNESCO; O'Donoghue, Taylor, & Venter, 2018).

One of the indicators of ESD is sustainable awareness, the practice of which can support 17 points in the sustainable development goals (SDGs) in everyday life. Sustainability awareness is defined as sustainable awareness that considers social, economic, and environmental aspects through caring for the environment in tackling global warming (Hamid *et al.*, 2017; Rini & Harto, 2022). Sustainability awareness is categorized into three: sustainability practice awareness, behavioral and attitude awareness, and emotional awareness (Hassan *et al.*, 2010). Students today may not have awareness due to not comprehending environmental dynamics or the potential effects of global warming on the environment. This condition is a challenge for teachers to form or develop sustainability awareness in students (Salsabila *et al.*, 2019).

One of the subjects that study material about the environment is science, which provides an understanding of the natural environment and its wealth. However, science learning still has challenges in developing students' interests, talents, and knowledge at this time, so it is relatively inefficient (Amalia & Hariyono, 2022). According to data from the Trend International Mathematics and Science Study (TIMSS), which focuses on science, Indonesia appears to occupy 46 out of 56 countries in the science benchmark level category because it gets points below 500 (Hadi & Novaliyosi, 2019). The achievement obtained by students in the field of science is low due to the tendency of students to memorize material, and it affects students' insufficient understanding (Septiari *et al.*, 2019). This condition is also supported by the use of conventional methods that refer to the teacher (teacher-centered) (Saidah & Nurita, 2017; Sumiatiningsih & Efendi, 2021), learning tools that are not aligned with the curriculum (Sukaesih *et al.*, 2019) and student worksheets (LKS) have not been able to accommodate students in understanding the subject matter and critical thinking (Dewi *et al.*, 2019). From these factors, it is known that teaching materials play an essential role as a helpful learning guide for teachers and students to achieve learning objectives through exciting content and a better learning process according to the conditions and needs of students (Maulida *et al.*, 2019; Safitri *et al.*, 2019; Ekamilasari & Pursitasari, 2021).

Modules can be defined as organized teaching materials that enable students to learn the material independently without guidance from the teacher (Puspitasari, 2019). Modules that are widely developed today are divided into two, namely electronic modules (e-

modules) and printed modules. The advantages of printed modules are that students from any region can use them, facilitate direct work on the sheets provided, and are effective in supporting problem-solving skills and creative thinking (Puspitasari, 2019). In its development, the module prioritizes understanding the concept and must relate it to everyday life (Pantiwati & Husamah, 2014). This study proposes an ESD-based module that goes beyond simply informing learners about climate change facts and science. It also emphasizes ESD principal of behavioral change practices, encouraging learners to take action and adopt new ethical perspectives in the face of a changing world. This module achieves this through co-engage processes that help learners identify issues of concern, assess their values, and take steps towards a more sustainable future (O'Donoghue, Taylor, & Venter, 2018).

Referring to the results of interviews conducted with science teachers of a public junior high school in Malang, it is known that currently, the use of teaching materials has failed to attract students in active learning, with much of learning process being predominantly teacher-directed. The science teacher of the subject school feels that ESD can help students practice understanding problems in the surrounding environment, think creatively, and be responsible for all their actions. The collaboration between science and ESD is anticipated to change the students' paradigm about science learning, which is not a memorization lesson and make students individuals who have a true learner ethos and are thirsty for knowledge and information. Most students also responded positively to the application of ESD in science learning because they felt that ESD is fascinating and has long-term benefits for the wider community. This perspective is in line with study from Benavot (2014) that stated It's a transformative process that fosters critical thinking, equipping students with the essential tools to reassess current policies, practices, and programs through the lens of sustainability standards. This empowers them to become agents of change, capable of driving a vital shift towards a more sustainable future (Benavot, 2014).

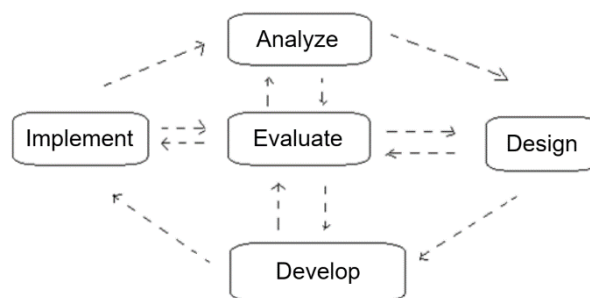
The close bond between science learning and ESD itself is evidenced by the vital role of science and technology in sustainable development in modern society (Eilks, 2015). The application of ESD in science learning has been carried out with various methods, integrating ESD in the model and developing learning tools (Purnamasari & Hanifah, 2021). The implementation of ESD-integrated learning models is stated to enhance critical thinking abilities, academic achievements, cognitive abilities, and sustainability awareness (Agusti *et al.*, 2019; Pratiwi *et al.*, 2019; Clarisa *et al.*, 2020). In another study, ESD applied to teaching tools improved problem-solving skills (Pradipta *et al.*, 2021). ESD can also be used in learning media through games (Fibonacci *et al.*, 2020). Rahman *et al.* (2019) and Almualimah *et al.* (2022) integrated ESD into teaching materials as modules. However, the research has not tested the effectiveness of ESD-based modules on specific competencies or learning outcomes.

Departing from the problems presented and the needs of students, this research focuses on developing and determining the effectiveness of teaching materials in ESD-based global warming modules. This teaching material was developed to encourage understanding and sustainability awareness and fulfill the need for ESD-based teaching materials.

## **Methods**

The research conducted follows a research and development (R&D) model, also known as an improvement model research to design, develop, and assessing the efficacy of products (Sugiyono, 2017). The product developed is a module with the basis of ESD. The research employs quasi-experimental design with equivalent control group designs (Sugiyono, 2019). The study population consisted of seventh-grade students attending a

public junior high school in Malang during the second semester of the 2022/2023 academic year, including nine classes totaling 304 students. The sampling technique uses purposive sampling or is selected based on specific considerations which are seen from the total number of students in each class ( $\leq 30$  students), taught by the same teacher, average data on the results of semester tests of seventh-grade students in science subjects and student activeness in learning based on information from the science teacher in that class. Ninety-four students participated in this study in total.



**Figure 1.** ADDIE Development Stage  
Source: (Tegeh and Kirna, 2013)

The ADDIE stages conducted in this study to develop the ESD-based module are described in Table 1.

**Table 1.** ESD-based Module Development Method

Stage	Activities	Data Collection Techniques	Subject
Analyse	Needs Analysis	Interview and questionnaire	54 students and 3 science teachers at a public junior high school in Malang
Design	1. Preparation of materials 2. Module design 3. Compilation of data collection instruments	-	-
Develop	Module design development		
	Module validation	Media validation questionnaire Material validation questionnaire	Media expert lecturer Material expert lecturer
Implement	Test the validity and reliability of the questions	Pretest-posttest question instrument	34 seventh-grade students of the subject school
	Readability test	Readability test questionnaire	30 seventh-grade students of the subject school
	Test the effectiveness of the module in increasing students' understanding	Pretest-posttest questions	60 seventh-grade students of the subject school

	and sustainability awareness	Sustainability awareness questionnaire	60 seventh-grade students of the subject school
Evaluate	Evaluate all steps taken.	Make revisions or improvements regarding input and suggestions from supervisors and validator lecturers to obtain valid product results.	

The data obtained were qualitative (interviews and suggestions on the validation test) and quantitative (final scores of the validation test, reliability test, readability test, and students' sustainability awareness scores, and pretest-posttest scores to test understanding). The questionnaires and validation instruments used a Likert scale (Likert, 1932). In validating the truth of the concept and the feasibility of the questions, a Guttman scale is used with two assessments: a score of 1 means correct, and a score of 0 means wrong (Sugiyono, 2019).

This study employed qualitative descriptive analysis methods along with percentage analysis, validity and reliability test, normality and homogeneity test, independent sample t-test, N-Gain testing, and effect size testing. In analyzing whether or not the product developed is valid use percentage analysis. The percentages of the validity test and readability test results are categorised into criteria as in Table 2.

**Table 2.** Percentage Criteria of validity and readability test

Validity and readability (%)	Criteria
81 – 100	Very valid/very good
61-80	Valid/good
41-60	Reasonably valid/good enough
21-40	Less valid/less good
0-20	Invalid/not good

(Source: Sofnidar & Yuliana, 2018)

The sustainability awareness questionnaire and pretest-posttest questions were used in the effectiveness test to see the increase in students' understanding and sustainability awareness. Before that, the validity and reliability tests were conducted on the pretest-posttest questions using IBM SPSS statistic 25 software. If the validity test of the pretest-posttest question obtained a correlation coefficient of more than 0.30, the question was declared valid (Sugiyono, 2019). Meanwhile, the reliability test of the pretest-posttest question is obtained for Cronbach's Alpha value; if the value >0.60, then the question is declared reliable (Dewi & Sudaryanto, 2020).

The scores from the sustainability awareness questionnaire and pretest-posttest were analyzed using SPSS software through the normality and homogeneity tests as a prerequisite for the independent sample t-test test. The independent sample t-test is a statistical test on whether or not the difference in mean values is based on two samples that are not interconnected (Sugiyono, 2019). If the significance value obtained from the Shapiro-Wilk normality test exceeds the predetermined threshold ( $\alpha \geq 0.05$ ), the data is considered to be normally distributed (Priyatno, 2009). In the homogeneity test, if the significance value is greater than the absolute level value ( $\alpha \geq 0.05$ ), then the data is declared to have homogeneous data variations (Ghozali, 2013). For the independent sample t-test, if the significance value obtained is greater than the absolute level ( $\alpha > 0.05$ ), then  $H_0$  is accepted, and  $H_1$  is rejected so that the two data groups are declared not significantly different. Conversely, if the significance value obtained is smaller than the absolute level ( $\alpha < 0.05$ ), then  $H_0$  is rejected and  $H_1$  is accepted (Wardani & Permatasari, 2022). The independent sample t-test operates based on the subsequent hypothesis:

$H_0$  : There is no significant difference between the two groups

$H_1$  : There is a significant difference between the two groups

The increase in students' sustainability awareness was analyzed by assessing the mean differences between the two groups using the independent sample t-test to determine if there was a notable distinction between the control and experimental classes. The criteria for students' awareness regarding sustainability are outlined in Table 3.

**Table 3.** Sustainability Awareness Categories

Average	Criteria
3.67-5.00	High
2.34-3.66	Medium
1.00-2.33	Low

(Source: Hassan et al., 2010)

In analyzing the increase in student understanding through the pretest-posttest, after the independent sample t-test is carried out, it is continued with the N-Gain test through the following equation:

$$N - \text{Gain} = \frac{\text{posttest score} - \text{pretest score}}{\text{ideal score} - \text{pretest score}} \quad (1)$$

(Source: Hake, 2002)

Based on the equation above, N-Gain results obtained are categorized according to the criteria in Table 4.

**Table 4.** N-Gain Categories

Score	Criteria
$0.70 \leq g \leq 1.00$	High
$0.30 \leq g < 0.70$	Medium
$0.00 \leq g < 0.30$	Low
$g = 0.00$	No improvement
$-1.00 \leq g < 0.00$	There was a decrease

(Source: Nismalasari et al., 2016)

Following the N-Gain test, an effect size assessment was performed to gauge the extent of influence one variable had on another variable (Dali, 2005). Cohen's d equation can be utilized to compute the effect size value (Santoso, 2010).

$$d = \frac{x_t - x_c}{SD} \quad (2)$$

$d$  = big influence

$x_t$  = experimental class average

$x_c$  = control class average

$SD$  = pooled standard deviation

The calculation of  $SD$  used the following equation:

$$SD = \sqrt{\frac{Sd_1^2 + Sd_2^2}{2}} \quad (3)$$

$SD$  = pooled standard deviation

$Sd_1^2$  = standard deviation of experimental class

$Sd_2^2$  = standard deviation of control class

Cohen's d value based on the equation above can be categorized according to the criteria in Table 5.

**Table 5.** Effect Size Criteria

Cohen's d effect size criteria	Value
High	0.8-2.0
Medium	0.5-0.7
Low	0.0-0.4

(Source: Vogt, 2015)

## Results and Discussion

The output of this research product is an ESD-based global warming module. This research was started by conducting a needs analysis at a subject school and involving science teachers and students in grades VIII and IX by interviewing three teachers who teach science materials. This study focuses on secondary level education due to its pivotal role during adolescence, the transitional phase between childhood and adulthood. During this period, significant physical, social, and cognitive changes occur, all of which interact with each other and the surrounding environment to shape the individual's journey into adulthood (National Academies of Sciences-Engineering and Medicine, 2019). By fostering sustainability literacy in this life phase, we can cultivate a generation of responsible citizens who actively contribute to a sustainable future.

The results are that the science learning at subject school has not integrated ESD, as evidenced by two of the three science teachers at the subject school still not recognizing ESD. Nevertheless, as agents of change, teachers must be able to orient themselves toward ESD (Tristananda, 2018). It is important for teacher to have understanding of concept, perceptions regarding sustainable development (SD) and sustainable development goals (SDGs), as well as comprehension of the rationale for integrating these concepts into their teaching, as well as their perspectives on this holistic and transdisciplinary integration, because their important role as central to the diffusion and delivery of ESD knowledge and skill sets (Fekih et al., 2022). Therefore, based on the needs analysis questionnaire, 92% of science teachers at SMP Negeri Pakis felt interested in using ESD-based teaching materials in learning. In addition, science teachers of subject schools rarely make or use modules during the learning process and only utilize school books and LKS. This condition is reinforced by Purnomo *et al.*'s (2013) assertion that most teachers do not prepare modules to support learning and apply them in class. The findings from the needs assessment also indicate that 82% of teachers require supplementary teaching resources besides package books and worksheets. In addition, based on the student needs analysis questionnaire that 54 respondents have conducted, it can be seen that 59% of students consider global warming material challenging to understand, 62% of students find it difficult to understand global warming material through worksheets, and 89% of students need science teaching materials that are packaged better and simpler so that they are easier to understand than package books or LKS.

The second stage is module design, which includes material preparation and module design. The global warming material is included in the climate change chapter and is the main topic of this chapter. This material refers to Almualimah *et al.* (2022), which is about global warming, such as definitions of efforts to tackle global warming. In addition, this stage also produced a draft design of the module to be developed.

The third phase involves development, which produces an ESD-based global warming module adapted to the design in printed modules in the previous stage. This ESD-based global warming module was developed using Canva® and Microsoft Word® software. This module consists of 47 pages with guidelines for use, material description, introduction to ESD, student learning activities, learning videos, literacy corner, independent summary, reflection, and competency test. Student learning activities include experiments, observing

phenomena based on videos or articles presented in the form of QR codes, and evaluating lifestyles. In this section, students are asked to assess whether they have implemented sustainable lifestyles in their daily lives. The literacy corner in this module contains information about natural phenomena related to global warming that expands knowledge and attracts students' curiosity. This condition is in line with Rifqiawati *et al.* (2017); the increase in interest in students can be triggered by objects or events taught by the teacher.

Following are the outcomes of the media validation for the ESD-based global warming module, depicted in Table 6.

**Table 6.** Media Validation Test Results

Aspects	Media score (%)	Criteria
Module size	100	Very valid
Cover design	100	Very valid
Illustration of contents	93.33	Very valid
Module content design	96	Very valid
Module quality	100	Very valid
Average	97.87	Very valid

The following validation results include material validation, concept correctness, and question feasibility. The results of validating the truth of the concept and the feasibility of the question obtained a percentage of 100% with very valid criteria. At the same time, the outcomes of the material validation are outlined in Table 7.

**Table 7.** Material Validation Test Results

Aspects	Percentage	Criteria
Content quality	96	Very valid
Quality of presentation	84	Very valid
Linguistic quality	96	Very valid
Average	92	Very Valid

The fourth step was implementation, which included a readability test, validity and reliability test of pretest-posttest questions, and effectiveness test. The outcomes of the readability examination for the module based on ESD are displayed in Table 8.

**Table 8.** Readability Test Results

Aspects	Percentage	Criteria
Content quality	84.53	Very good
Evaluation	88.22	Very good
View	88.93	Very good
Language	83.33	Very good
Average	86.25	Very good

Before conducting the effectiveness test, the five pretest-posttest essay questions that the materials validated by experts underwent testing for validity and reliability utilizing SPSS. Validity itself refers to the effectiveness of a study (Loewen and Plonsky, 2016), this refers to the degree to which the findings of the research can effectively address the formulated questions (Révész, 2012; Gravetter & Forzano, 2018). The validity test results show that the five pretest-posttest items have a correlation coefficient  $>0.30$ , so the five questions are declared valid. Meanwhile, reliability pertains to how consistently measurements or experimental procedures can produce interpretations of the constructs identified for measurement (Rogers & Revesz, 2019). The Cronbach's Alpha value obtained



through the reliability test is  $0.637 > 0.60$ , so the pretest-posttest questions are said to be reliable.

In implementing the effectiveness test, data was collected for four meetings, which is equivalent to 10 lesson hours for 400 minutes. In the data collection process, the control class conducted conventional learning activities using the lecture method, while the experimental class applied the ESD-based module that had been developed. For the experimental class, the pretest and sustainability awareness (SA) questionnaires were conducted in the first meeting, as well as the study of subchapter 1, namely the greenhouse effect. Students learned the concept of the greenhouse effect through the learning video in the module by scanning the QR code. In the second meeting, students studied subchapters 2 and 3: the definition and factors that cause global warming. Student activities at this meeting are reading news articles provided in the form of QR codes to analyze what causes global warming. In the third meeting, students studied subchapters 4 and 5, namely the consequences of global warming and efforts to overcome it. Students are introduced to a sustainable lifestyle, where they then conduct a self-assessment regarding how sustainable the lifestyle they apply in their daily lives is. In the fourth meeting, the SA post-test and post-questionnaire were conducted.

The effectiveness test data, which includes a pretest, post-test, SA pre questionnaire, and post-questionnaire data from the control and experimental classes, are then processed through the normality test. The outcomes of the normality test indicated that the data from both the control and experimental classes were normally distributed. However, the homogeneity test results revealed that the pretest and post-test data were deemed heterogeneous, whereas the SA pre-questionnaire and SA post-questionnaire data were considered homogeneous.

Normality and homogeneity tests are prerequisites before proceeding to the independent sample t-test. However, if the data is not homogeneous, it can continue with the independent sample t-test unequal variance test (Usmadi, 2020). The outcomes of the independent sample t-test are presented in Table 9.

**Table 9.** Independent Sample T-Test Results

Data	Significance Value
Pretest	0.753
Post-test	<0.001*
SA Pre questionnaire	0.903
SA Post questionnaire	<0.001*

\*asterisk means significant difference

According to the independent sample t-test, there is a notable variance in the mean value of the SA post-questionnaire between the control and experimental classes. Table 10 displays the mean scores of the sustainable awareness questionnaire for both the control and experimental classes across three categories.

**Table 10.** Results of Average Sustainability Awareness Questionnaire Score

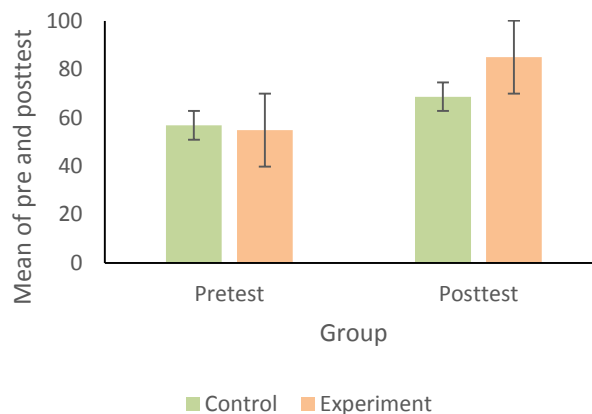
SA Category	Control Class				Experiment Class			
	Pre	SA Criteria	Post	SA Criteria	Pre	SA Criteria	Post	SA Criteria
Sustainability practice awareness (3, 9, 10, 13, 14)	2.50	Medium	2.96	Medium	2.52	Medium	3.56	Medium

Behavioral and attitude awareness (1, 6, 7, 8, 11, 12)	2.77	Medium	3.19	Medium	2.76	Medium	3.67	High
Emotional awareness (2, 4, 5, 15)	2.92	Medium	3.17	Medium	2.87	Medium	3.98	High
	2.73	Medium	3.11	Medium	2.71	Medium	3.74	High

Based on Table 10, the control class observed a rise in the mean score of the sustainability awareness questionnaire. However, it did not show an increase in sustainability awareness criteria in the three categories included in the moderate criteria. On the other hand, the experimental class witnessed a rise in the mean score of the sustainability awareness questionnaire across every sustainability awareness category. The average increase was followed by an increase in criteria in the behavioral and attitude awareness, and emotional awareness categories. The data indicates that the experimental class, which is the class that utilizes the ESD-based global warming module, the sustainability awareness, as measured by the average pre-questionnaire score, saw a rise of 2.71 from a maximum scale of 5.00, indicating moderate criteria. This increased to 3.74 on the average post-questionnaire, demonstrating high criteria. The result is supported by the opinion of Aliman *et al.* (2019), who expect ESD to form students who have sustainability awareness, especially in overcoming global problems, and can think critically to solve problems by analyzing the impact of damage in various aspects of life.

The data above shows that students have not yet integrated to practice sustainability awareness in their daily lives even though they know the importance of sustainability awareness. This result is agreed by Ekamilasari & Pursitasari (2021) and Hassan *et al.* (2010), who stated that emotionally students already care about their surroundings but still find it challenging to act and apply behaviors that show concern for the environment. One of the external factors that influenced the results of the SA questionnaire incorporated the teacher's role in the classroom, where the teacher who taught in the control class differed from the experimental class. Teachers who teach in control classes have better competence and experience than teachers in experimental classes, so the results obtained are not too significant. This corroborated by Rakib *et al.* (2017), who asserted that teachers with extensive teaching experience and tenure tend to possess elevated teaching competence.

Apart from the pre and post-data from the SA questionnaire, the independent sample t-test was also employed to analyze the pretest and post-test data between the control and experimental classes. Through this test, it appears that there exists a notable contrast between the mean post-test outcomes of the control class, which stood at 68.67, and those of the experimental class, which were recorded at 85, where the average pretest value of the two is not significantly different, namely the control pretest average of 56.83 and the experimental class of 54.83. The mean pretest and post-test scores of the control and experimental classes are shown in Figure 2.



**Figure 2.** Mean of Pretest and Posttest in Control and Experimental Classes with Error Bars Indicating Standard Deviation

After that, the N-Gain test was carried out on the pretest and post-test scores to determine the increase in student understanding. The pretest and post-test N-Gain test results from the control and experimental classes appear in Table 11.

**Table 11.** Pretest-Posttest N-Gain Test Results

Class	N-Gain	Criteria
Control	0.27	Low
Experiment	0.67	Medium

Understanding involves developing the capacity to derive significance from information, which includes enhancing the ability to interpret, elucidate, deduce, analyze connections, and apply acquired knowledge to different situations (Natali, 2017). In this case, to measure students' understanding of global warming material, five pretest-posttest questions were used in the cognitive domain of C4 (analyze) and C5 (evaluate).

Referring to Figure 2, both classes showed an increase in post-test scores, with experimental scores superior to the control class. Therefore, it can be concluded that the experimental class comprehends more sophisticated concepts compared to the control class. This corresponds with the findings of Septiari *et al.* (2019), who conveyed that higher post-test scores reveal higher or superior concept interpretation. The N-Gain test also shows a considerable increase in the experimental class after using the ESD-based module.

Following the N-Gain test, the effect size test proceeds to assess the extent of influence one variable has on another (Dali, 2005). In this study, the effect size test was utilized to ascertain the impact of the ESD-based global warming module on enhancing students' understanding. The outcome of the effect size test conducted on the average post-test scores of the control and experimental classes showed the acquisition of a Cohen's d score of 1.30 with high criteria.

The data from the effect size test showed that using ESD-based modules significantly increased students' knowledge of global warming material by a percentage of 90%. In line with the statement of Brigenta *et al.* (2017), which states that a learning module can increase student understanding by presenting exciting and reliable data and facilitating data processing. Student understanding can continue to be improved by using an exciting and student-centered learning process so that students do not experience monotony merely from listening to the teacher's explanations stated by Septiari *et al.* (2019) that the lack of active students learning due to boredom will affect the low understanding of student

concepts. Therefore, this ESD-based global warming module has engaging content and learning activities to help students understand concepts more optimally.

## Conclusion

The product, presented as an ESD-based module, has successfully undergone validation by both media and material experts with very valid criteria. In addition, the results of the N-Gain test on the post-test of the experimental class showed moderate criteria. They were supported by the findings of the effect size test on the post-test of both the control experimental classes, which showed high criteria. Developing an ESD-based global warming module can increase junior high school student's understanding and sustainability awareness. From this, it can be inferred that the ESD-centered global warming module developed in this study was both valid and efficacious.

## References

- Agusti, K.A., Wijaya, A.F.C., & Tarigan, D.E. 2019. Problem based learning dengan konteks ESD untuk meningkatkan keterampilan berpikir kritis dan sustainability awareness siswa SMA pada materi pemanasan global. *Prosiding Seminar Nasional Fisika*, VIII: 175-182. <https://doi.org/10.21009/03.snf2019.01.pe.22>.
- Aliman, M., Budijanto, Sumarni, & Astina, I.K. 2019. Improving environmental awareness of high school students in Malang city through earthcomm learning in the geography class. *International Journal of Instruction*, 12(4):79-94. <https://doi.org/10.29333/iji.2019.1246a>.
- Almualimah, V.A., Maulida, S.N., & Nurfitasari. 2022. Pengembangan smart modul IPA berbasis education for sustainable development pada konsep perubahan iklim untuk siswa kelas VII SMP. *Proceeding of Integrative Science Education Seminar*, 2(1): 113-124.
- Amalia, A. & Hariyono, E. 2022. Penerapan experiential learning pada materi perubahan iklim untuk melatih keterampilan berpikir kritis siswa. *Briliant: Jurnal Riset dan Konseptual*, 7(1):134-144. <https://doi.org/10.28926/briliant.v7i1.934>.
- Benavot, A. 2014. *Education for Sustainable Development in Primary and Secondary Education Networking to Integrate SDG Target 4.7 and SEL into Educational Materials*. <https://doi.org/10.13140/RG.2.1.1978.9283>
- Brigenta, D., Handhika, J., & Sasono, M. 2017. Pengembangan modul berbasis discovery learning untuk meningkatkan pemahaman konsep. *Prosiding Seminar Nasional Pendidikan Fisika*, III:167-173.
- Brundiers, K. & Wiek, A. 2013. Do we teach what we preach? An international comparison of problem- and project-based learning courses in sustainability. *Sustainability (Switzerland)*, 5(4): 1725-1746. <https://doi.org/10.3390/su5041725>.
- Clarisa, G., Danawan, A., Muslim, & Wijaya, A.F.C. 2020. Penerapan flipped classroom dalam konteks ESD untuk meningkatkan kemampuan kognitif dan membangun sustainability awareness siswa. *Journal of Natural Science and Integration*, 3(1):13-25. <https://doi.org/10.24014/jnsi.v3i1.8953>.

- Dewi, S.K. & Sudaryanto, A. 2020. Validitas dan reliabilitas kuesioner pengetahuan, sikap dan perilaku pencegahan demam berdarah. *Seminar Nasional Keperawatan Universitas Muhammadiyah Surakarta (SEMNASKEP) 2020*, pp. 73–79.
- Dewi, S.M., Gunawan, Susilawati, & Harjono, A. 2019. Validitas perangkat pembelajaran fisika berbasis model generatif berbantuan laboratorium virtual. *Jurnal Pendidikan Fisika dan Teknologi*, 5(1):162–166. <https://doi.org/10.29303/jpft.v5i1.1175>.
- Eilks, I. 2015. Science education and education for sustainable development - justifications, models, practices and perspectives. *Eurasia Journal of Mathematics, Science and Technology Education*, 11(1):149–158. <https://doi.org/10.12973/eurasia.2015.1313a>.
- Ekamilasari, E. & Pursitasari, I.D. 2021. Students' critical thinking skills and sustainability awareness in science learning for implementation education for sustainable development. *Indonesian Journal of Multidisciplinary Research*, 1(1):121–124. <https://doi.org/10.17509/ijomr.v1i1.33792>.
- Ergin, D.Y. 2019. Environmental awareness of teacher candidates. *World Journal of Education*, 9(1):152-161. <https://doi.org/10.5430/wje.v9n1p152>.
- Fekih Zguir, M., Dubis, S., & Koç, M. 2022. Integrating sustainability into curricula: Teachers' perceptions, preparation and practice in Qatar. *Journal of Cleaner Production*, 371:1-18. <https://doi.org/10.1016/j.jclepro.2022.133167>
- Fibonacci, A., Azizati, Z., & Wahyudi, T. 2020. Development of education for sustainable development (ESD) based chemsdro mobile based learning for indonesian junior high school: rate of reaction. *JTK (Jurnal Tadris Kimiya)*, 5(1):26–34. <https://doi.org/10.15575/jtk.v5i1.5908>.
- Ghozali, I. 2013. *Aplikasi Analisis Multivariate dengan Program SPSS*. Badan Penerbit Universitas Diponegoro, Semarang.
- Gravetter, F. & Forzano, L. 2018. *Research methods for the behavioral sciences*. Cengage, Boston.
- Hadi, S. & Novaliyosi. 2019. Trends in International Mathematics and Science Study (TIMSS). *Prosiding Seminar Nasional & Call For Papers*, pp. 562–569. [https://doi.org/10.1007/978-94-6209-497-0\\_97](https://doi.org/10.1007/978-94-6209-497-0_97).
- Hake, R.R. 2002. Relationship of individual student normalized learning gains in mechanics with gender, high-school physics, and pretest scores on Mathematics and Spatial Visualization. *Physics Education Research Conference*, 8(August 2002): 1–14.
- Hamid, S., Ijab, M.T., Sulaiman, H., Md. Anwar, R. & Norman, A.A. 2017. Social media for environmental sustainability awareness in higher education. *International Journal of Sustainability in Higher Education*, 18(4):474–491. <https://doi.org/10.1108/IJSHE-01-2015-0010>.
- Hassan, A., Noordin, T.A., & Sulaiman, S. 2010. The status on the level of environmental awareness in the concept of sustainable development amongst secondary school students. *Procedia - Social and Behavioral Sciences*, 2(2):1276–1280.

<https://doi.org/10.1016/j.sbspro.2010.03.187>.

- Japan National Commission for UNESCO. (n.d.). *A Guide to Promoting ESD (Education for Sustainable Development)*. Retrieved from Ministry of Education, Culture, Sports, Science and Technology (MEXT) Japan: [https://www.mext.go.jp/component/english/icsFiles/afiedfile/2016/11/21/1379653\\_01\\_1.pdf](https://www.mext.go.jp/component/english/icsFiles/afiedfile/2016/11/21/1379653_01_1.pdf)
- Kalsoom, Q. & Khanam, A. 2017. Inquiry into sustainability issues by preservice teachers: A pedagogy to enhance sustainability consciousness. *Journal of Cleaner Production*, 164:1301-13011. <https://doi.org/10.1016/j.jclepro.2017.07.047>.
- Klarin, T. 2018. The concept of sustainable development: from its beginning to the contemporary issues. *Zagreb International Review of Economics and Business*, 21(1): 67–94. <https://doi.org/10.2478/zireb-2018-0005>.
- Likert, R.A. 1932. Technique for Measurement of Attitudes. *Archives of Psychology*, 22 (140):5-55.
- Loewen, S. & Plonsky, L. 2016. *An A-Z of Applied Linguistics Research Methods*. Palgrave Macmillan, London.
- Marianta, Y.I.W. 2011. Akar krisis lingkungan hidup. *Studia Philosophica et Theologica*, 11(2):231-253. <https://doi.org/10.35312/spet.v11i2.72>.
- Maulida, H., Sinaga, P., & Susilawati, M. 2019. Pengembangan bahan ajar IPA terpadu berbasis android berorientasi keterampilan berpikir kritis. *Jurnal Petik*, 5(1):70–76. <https://doi.org/10.31980/jpetik.v5i1.492>.
- Natali, S.S. 2017. Analisis tingkat pemahaman siswa berdasarkan teori APOS pada materi persamaan kuadrat ditinjau dari minat belajar siswa kelas X SMA Negeri 2 Surakarta tahun ajaran 2015/2016. *Jurnal Pendidikan Matematika dan Matematika (JPMM) Solusi*, 1(5):104–117. <https://jurnal.fkip.uns.ac.id/index.php/matematika/article/view/11635>.
- Nismalasari, Santiani, & Rohmadi, H.M. 2016. Penerapan model pembelajaran learning cycle terhadap keterampilan proses sains dan hasil belajar siswa pada pokok bahasan getaran harmonis. *EduSains*, 4(2):74–94. <https://e-journal.iain-palangkaraya.ac.id/index.php/edusains/article/view/511>.
- Novidsa, I., Purwianingsih, W., & Riandi, R. 2020. Exploring knowledge of prospective biology teacher about education for sustainable development. *JPBI (Jurnal Pendidikan Biologi Indonesia)*, 6(2):317–326. <https://doi.org/10.22219/jpbi.v6i2.12212>.
- Ntanos, S., Kyriakopoulos, G.L., Arabatzis, G., Palios, V., & Chalikias, M. 2018. Environmental behavior of secondary education students: A case study at central Greece. *Sustainability (Switzerland)*, 10(5):1–22. [https://doi.org/10.3390/su10\\_051663](https://doi.org/10.3390/su10_051663).
- Nursadiyah, Suyana, I., & Ramalis, T.R. 2018. Profil sustainability awareness siswa melalui integrasi ESD dalam pembelajaran berbasis masalah pada topik energi di SMP. *Prosiding Seminar Nasional fisika (SINAFI)*, 2018 January, p.207–212.

- O'Donoghue, R., Taylor, J., & Venter, V. (2018). How are learning and training environments transforming with ESD? In A. Leicht, J. Heiss, & J. B. Won, *Issues and trends in education for sustainable development* (pp. 108-128). Paris: UNESCO.
- Pantiwati, Y. & Husamah. 2014. Analisis kemampuan literasi sains siswa SMP Kota Malang. *Prosiding Konferensi Ilmiah Tahunan Himpunan Evaluasi Pendidikan Indonesia (Hepi)*, 2014 September, p.158-174.
- Pradipta, D.D., Madlazim, & Hariyono, E. 2021. The effectiveness of science learning tools based on education sustainable development (ESD) to improve problem-solving skills. *IJORER : International Journal of Recent Educational Research*, 2(3):342-353. <https://doi.org/10.46245/ijorer.v2i3.113>.
- Pratiwi, I.I., Wijaya, A.F.C., & Ramalis, T.R. 2019. Penerapan PBL dengan konteks ESD untuk meningkatkan hasil belajar kognitif peserta didik. *Prosiding Seminar Nasional Fisika*, VIII:1-8. <https://doi.org/10.21009/03.snf2019.01.pe.01>.
- Priyatno, D. 2009. *Jam Belajar Olah Data dengan SPSS*. Elex Media Komputindo, Yogyakarta.
- Purnamasari, S. & Hanifah, A.N. 2021. Education for sustainable development (ESD) dalam pembelajaran IPA. *Jurnal Kajian Pendidikan IPA*, 1(2):69-75. <https://doi.org/10.52434/jkpi.v1i2.1281>.
- Purnomo, D., Indrowati, M., & Karyanto, P. 2013. Pengaruh penggunaan modul hasil penelitian pencemaran di Sungai Pepe Surakarta sebagai sumber belajar biologi pokok bahasan pencemaran lingkungan terhadap hasil belajar siswa. *Jurnal Pendidikan Biologi*, 5(1): 59-69. <https://jurnal.fkip.uns.ac.id/index.php/bio/article/view/1439>.
- Puspitasari, A.D. 2019. Penerapan media pembelajaran fisika menggunakan modul. *Jurnal Pendidikan Fisika*, 7(1):17-25. <https://doi.org/10.24252/jpf.v7i1.7155>.
- Rahmah, D.M. 2022. Perubahan iklim dalam pendidikan IPA berkelanjutan. *Jurnal Sains Edukatika Indonesia*, 4(2):20-25. <https://jurnal.uns.ac.id/jsei/article/view/70940>.
- Rahman, A., Heryanti, L.M., & Ekanara, B. 2019. Pengembangan modul berbasis education for sustainable development pada konsep ekologi untuk siswa kelas X SMA. *Jurnal Eksakta Pendidikan (JEP)*, 3(1):1-8. <https://doi.org/10.24036/jep/vol3-iss1/273>.
- Rakib, M., Rombe, A., & Yunus, M. 2017. Pengaruh pelatihan dan pengalaman mengajar terhadap profesionalitas guru. *Jurnal Ad'ministrare*, 3(2):137-148. <https://doi.org/10.26858/ja.v3i2.2574>.
- Révész, A. 2012. Coding second language data validly and reliably, in *In A. Mackey & S. M. Gass (Eds.), Research methods in second language acquisition: A practical guide*. Wiley-Blackwell, Oxford, pp. 203-221.
- Rifqiawati, I., Wahyuni, I., & Rahman, A. 2017. Pengaruh metode field trip dengan pemanfaatan rumpon buatan terhadap keterampilan proses sains dan sikap ilmiah di SMP Satu Atap Pulau Tunda. *Biodidaktika Jurnal Biologi dan Pembelajarannya*, 12(1): 23-30. <https://doi.org/10.30870/biodidaktika.v12i1.1832>.



- Rini, N.W. & Harto, N. 2022. Profil sustainability awareness siswa SMA/SMK pada materi suhu dan energi. *Jurnal Sains dan Pendidikan Fisika*, 18(1):68–76. <https://doi.org/10.35580/jspf.v18i1.21535>.
- Rogers, J. & Revesz, A. 2019. Experimental and, in *The Routledge Handbook of Research Methods in Applied Linguistics*. Taylor & Francis, New York.
- Safitri, A., Festiyed, & Putra, A. 2019. Desain modul interaktif menggunakan aplikasi course lab berbasis pendekatan saintifik pada materi usaha, energi, dan momentum. *Jurnal Pillar of Physics Education*, 12(3):433–440. <https://ejournal.unp.ac.id/students/index.php/pfis/article/view/6971>.
- Saidah, R.N. & Nurita, T. 2017. Keterampilan pemecahan masalah IPA siswa SMP kelas VIII pada materi tekanan zat cair. *E-Journal Pensa*, 5(3):226–231. <https://www.neliti.com/publications/253064/keterampilan-pemecahan-masalah-ipa-siswa-smp-kelas-viii-ada-materi-tekanan-zat-cair#cite>.
- Salsabila, E.R., Wijaya, A.F.C., & Winarno, N. 2019. Improving students' sustainability awareness through argument-driven inquiry. *Journal of Science Learning*, 2(2):58–65. <https://doi.org/10.17509/jsl.v2i2.13104>.
- Santoso, A. 2010. Studi deskriptif effect size penelitian-penelitian di fakultas psikologi Universitas Sanata Dharma. *Jurnal Penelitian, Fakultas Psikologi Universitas Sanata Dharma, Yogyakarta*, 14: 17. <http://repository.usd.ac.id/id/eprint/9419>.
- Segara, N.B. 2015. Education for sustainable development (ESD) sebuah upaya mewujudkan kelestarian lingkungan. *SOSIO DIDAKTIKA: Social Science Education Journal*, 2(1):22–30. <https://doi.org/10.15408/sd.v2i1.1349>.
- Septiari, N.K.D., Suardana, I.N., & Selamat, K. 2019. Efektivitas model pembelajaran inkuiri terbimbing dalam meningkatkan pemahaman konsep IPA siswa SMP. *Jurnal Pendidikan dan Pembelajaran Sains Indonesia (JPPSI)*, 1(1):45–56. <https://doi.org/10.23887/jppsi.v1i1.21917>.
- Simbolon, A.M. 2021. Education for sustainable development in Indonesia: Developing online sustainable development learning model based on Indonesian typical case studies. *Proceedings of the International Conference on Educational Sciences and Teacher Profession (ICETeP 2020)*, 532(532):43–49. <https://doi.org/10.2991/assehr.k.210227.008>.
- Sofnidar, S. & Yuliana, R. 2018. Pengembangan media melalui aplikasi adobe flash dan photoshop berbasis pendekatan saintifik. *Jurnal Gentala Pendidikan Dasar*, 3(2): 257–275. <https://doi.org/10.22437/gentala.v3i2.6761>.
- Sugiyono. 2019. *Metode Penelitian Kuantitatif, Kualitatif dan R&D*. Alfabet, Bandung.
- Sukaesih, S., Ridlo, S., & Saptono, S. 2019. Development of biology teaching management textbooks based on competency and conservation to maximize Pedagogical and Content Knowledge ( PCK ) the prospective teachers. *Journal of Physics: Conference Series*, 1321(3):1–6. <https://doi.org/10.1088/1742-6596/1321/3/032114>.
- Sukananda, S. & Nugraha, D.A. 2020. Urgensi penerapan analisis dampak lingkungan



- (AMDAL) sebagai kontrol dampak terhadap lingkungan di Indonesia. *Jurnal Penegakan Hukum dan Keadilan*, 1(2): 119–137. <https://doi.org/10.18196/jphk.1207>.
- Sumiatiningsih & Efendi, N. 2021. The student problem solving skills in science subjects based on class rankings. *Academia Open*, 5:1–10. <https://doi.org/10.21070/acopen.5.2021.2240>.
- Suwarto, R.S., Sanjaya, Y., & Solihat, R. 2021. Implementation of education for sustainable development and pupils' sustainability consciousness in Adiwiyata School and ESD-based school. *Journal of Physics: Conference Series*, 1806(1). <https://doi.org/10.1088/1742-6596/1806/1/012153>.
- Tegeh, I.M. & Kirna, I.M. 2013. Pengembangan bahan ajar metode penelitian pendidikan dengan ADDIE model. *Jurnal IKA*, 11(1):12–26. <https://doi.org/10.23887/ika.v11i1.1145>.
- Tristananda, P.W. 2018. Membumikan education for sustainable development (ESD) di Indonesia dalam menghadapi isu-isu global. *Purwadita*, 2(2):42–49. <https://doi.org/10.55115/purwadita.v2.i2.86>.
- UNESCO. 2009. *Review of contexts and structures for education for sustainable development 2009: key findings & ways forward*. Retrieved from UNESCO Digital Library: <https://unesdoc.unesco.org/ark:/48223/pf0000187757>
- UNESCO. 2017. *Education for Sustainable Development Goals: Learning Objectives. Education for Sustainable Development. The Global Education 2030 Agenda*. [www.unesco.org](http://www.unesco.org)
- Usmadi, U. 2020. Pengujian persyaratan analisis (uji homogenitas dan uji normalitas). *Inovasi Pendidikan*, 7(1):50–62. <https://doi.org/10.31869/ip.v7i1.2281>.
- Vogt, W. 2015. Effect size (ES). *Dictionary of Statistics & Methodology* [Preprint], (1993). <https://doi.org/10.4135/9781412983907.n624>.
- Wangid, M.N. 2018. Sainsmatika-based story tale book to improve environmental awareness of 4th grades students. *Jurnal Inovasi Pendidikan IPA*, 4(1):128–135. <https://doi.org/10.21831/jipi.v4i1.21706>.
- Wardani P.S., & Permatasari I.R. 2022. Pengaruh pengembangan karier dan disiplin kerja terhadap prestasi kerja pegawai negeri sipil (PNS) staf umum bagian pergudangan penerbangan angkatan darat (PENERBAD) di Tangerang. *Jurnal Ilmiah M-Progress*, 12(1):13–25. <https://doi.org/10.35968/m-pu.v12i1.862>.
- Wihardjo, S.D., Hartati, S., Nurani, Y., & Sujarwanta, A. 2017. The effects of green schooling knowledge level and intensity of parental guidance on the environmental awareness of the early age student. *Educational Research and Reviews*, 12(5):251–257. <https://doi.org/10.5897/err2015.2608>.