

# Development of Global Warming E-Module Based on Socio Scientific Issues (SSI) to Improve Students' Critical Thinking Skills and Sustainability Awareness

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**Abstract:** The Research and Development study aims to produce a global warming E-Module based on Socio Scientific Issues (SSI) to improve students' critical thinking skills and sustainability awareness. The research and development design used is the ADDIE (Analysis Design Development Implementation Evaluation) model design. The research subjects for e-module implementation were 38 students of class X SMA Negeri 3 Cibinong. Research data were obtained through e-module validation questionnaire, critical thinking skills essay questions, sustainability awareness questionnaire, and student response questionnaire. Data analysis techniques using shapiro wilk, paired sample t-test. Based on the research results, it can be concluded that the SSI-based global warming e-module is valid/suitable for use in terms of feasibility (content, presentation and language), as well as in terms of media with the percentages respectively being 91% and 97%. The CVI results related to the feasibility of the e-module are 0.99 (valid). Learning using the SSI-based global warming e-module can improve students' critical thinking skills in the high category with an average score of N-Gain critical thinking skills of 0.78. Learning using the SSI-based global warming e-module can increase students' sustainability awareness in the medium category with an average N-Gain sustainability awareness score of 0.45. Student responses to the SSI-based global warming e-module were very good with an average score percentage of 91%.

**Keywords:** Critical Thinking Skills; Socio Scientific Issues; Sustainability Awareness.

## Introduction

Various changes occur in the world of knowledge, technology and information globally. However, from these changes negative impacts emerge, such as global warming, the energy crisis and environmental damage (Dawson & Carson, 2020). This causes there to be no balance between the benefits of scientific and technological development and the impact on the environment. The development of science and technology has not been processed with efforts to minimize its impact on the environment (Romine et al.,

2020). Environmental problems that occur, such as global climate change, are the result of human activities that do not care about environmental conditions (İpek Akbulut & Demir, 2020). Based on a report from The Intergovernmental Panel on Climate Change (IPCC) in April 2022 which was approved by 195 countries, human activities are estimated to have caused global warming to reach 1.5°C. Global temperatures will stabilize if world carbon dioxide emissions reach net zero. To limit the increase in earth's temperature to 1.5°C, net zero carbon dioxide should be achieved as

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early as 2050 while for 2°C in 2070 (Dawson & Carson, 2020)

The world of education needs to respond through learning to solve environmental problems. One learning alternative that suits these characteristics is Socio Scientific Issues (SSI) based learning. SSI creates contextual learning conditions to develop critical thinking skills, argumentation, exploring issues, developing moral reasoning and reflective judgment abilities (Zeidler & Nichols, 2009). SSI presents complex problems related to science (Romine et al., 2017). SSI makes students use science knowledge in a social context which can help when faced with complex problems (Ke et al., 2021). If students already understand SSI, then their ability to make decisions will be good (Geopany et al., 2021). SSI is used in making decisions such as social issues regarding antibiotics, transgenic crops, biotechnology and the environment (Hancock et al., 2019). SSI based learning raises environmental issues in social life in order to hone students' awareness (Susilawati et al., 2021).

On the other hand, the world of education is faced with 21st century skills which are characterized as the century of openness or the century of globalization, meaning that human life in the 21st century is experiencing changes (Widiyanti & Kurniawan, 2021). 21st century education is needed to support students to have skills through the learning process, innovation, technology so they can survive to support life (Salsabila et al., 2019). The results of preliminary tests on 38 students at public high schools in Bogor Regency showed that the average score of students' critical thinking skills was 19.01%, which means that students' critical thinking skills were still in the low category.

Implementing SSI is very important to resolve issues that are currently developing in society (Leung, 2021) so it becomes a problem for humans who provide context for (Ottander & Simon, 2021) learn scientific concepts and explore the relationship between science, the environment and health so that it is hoped that it can foster a sense of awareness, attitudes and values in students (Sadler et al., 2006). The results of observations of sustainability awareness from 52 public high school students in Bogor Regency were 56.73%, which shows that sustainability awareness is still low.

The need for innovative teaching materials develops in accordance with the needs of science (Manasikana, 2017). The teaching materials developed can encourage effective, independent learning and help students acquire the necessary skills (Manasikana, 2017). One of the teaching materials that can be applied in schools is electronic-based learning modules (Widiyanti & Kurniawan, 2021).

Based on the results of previous research related to SSI with efforts to improve critical thinking skills and

sustainability awareness, no research has been conducted using e-modules. E-Module is a computer-based teaching material containing material that makes it easier for users to understand material containing text, images, animations and videos with technological advances that can be used via smartphone so that the use of the module is not limited by place and time (Widiyanti & Kurniawan, 2021). The material used is global warming because it is one of the materials currently being debated.

E-module is a digital learning resource that can help teachers and students in learning that is easy to access independently (Rismayanti et al., 2022). Based on the results of a questionnaire on the needs of science teachers in Bogor Regency, only 21.6% of teachers implemented learning modules, most teachers used textbooks provided by the government to support learning. Based on the background of the problem, the problem formulation is how an e-module based on Socio Scientific Issues on Global Warming material can improve critical thinking skills and sustainability awareness of class X students at SMA Negeri 3 Cibinong.

## Method

This research uses quasi-experiment. The research method used is research and development (R&D) with the ADDIE (Analysis Design Development Implementation Evaluation) model developed by Branch. The research subjects used in this study were 38 class X students at SMA Negeri 3 Cibinong, Bogor Regency. Other research subjects were 20 science teachers and 2 lecturers each who were media and materials experts. The product developed is an SSI-based global warming e-module to improve critical thinking skills and sustainability awareness for class X high school students. The e-module development flow using the ADDIE model is as follows:

### *Analysis Stage*

The initial stage of this research is analyzing the problems that occur to be resolved with the right solution. At the analysis stage there are several analyzes carried out, namely (1) analysis of the need for teaching materials that support 21st century skills (2) curriculum analysis which aims to analyze the curriculum used so that students can achieve learning, (3) analyze the lesson material that will be used in learning activities (4) analysis of critical thinking skills and sustainability awareness using literature studies, interviews and tests.

### *Design Stage*

The design stage is collecting literature for the e-module as a stage for collecting various references that

will be used as material for compiling the e-module that will be created. Create an e-module design that is tailored to the predetermined learning outcomes which will be reduced to learning objectives. Develop instruments for critical thinking skills and sustainability awareness. Designing a global warming e-module story board.

*Development Stage*

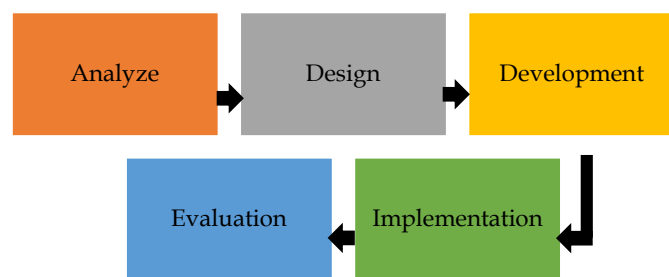
The development stage is the activity of realizing the product design in the research in the form of an e-module. Products that have been created will be validated and revised by experts. Validation is carried out by experts or experts who are competent in their field. The validation carried out consisted of media experts and material experts. Validation aims to correct errors in the e-module being developed. After the experts declare it feasible, the e-module can be used for limited trials with students at SMA Negeri 3 Cibinong.

*Implementation Stage*

The implementation stage was carried out to determine the results of learning using the global warming e-module for class X students at SMA Negeri 3 Cibinong as many as 38 students. At this stage, analysis is carried out by comparing the average value of critical thinking skills and sustainability awareness before and after using the e-module with the One Group Pretest and Posttest Design Technique.

*Evaluation Stage*

The e-module is evaluated according to the results obtained based on the analysis at the implementation stage. At the evaluation stage, revisions were made to the final stage of the e-module which was developed based on input and suggestions from student and teacher responses after using the e-module.



**Figure 1.** Adaptation of the ADDIE learning model by Branch

*Research Instrument*

The instruments used in the initial stages of research, development and at the end of the research are as follows e-module validation research instruments by media experts and material experts from expert/lecturer judgment circles according to their field. Research

instruments to measure critical thinking skills using essay type written tests. The research instrument for measuring sustainability awareness uses non-tests in the form of questionnaires. Research instrument to determine student and teacher responses to the global warming e-module based on Socio Scientific Issues (SSI) to improve students' critical thinking skills and sustainability awareness using non-tests in the form of questionnaires.

*Data analysis technique*

The data analysis techniques used are as follows validity of the e-module using the Lawshe Content Validity Ratio (CVR) and Content Validity Index (CVI) methods. Test the validity of the critical thinking skills instrument using the Product Moment correlation formula and test the reliability using Cronbach's Alpha. Analysis of improving critical thinking skills using N-Gain to calculate the increase in students' pretest and posttest scores. Analysis of sustainability awareness results using a Likert Scale with five answer choices with the lowest value being 1 and the highest value being 5, namely: strongly agree (5), agree (4), doubtful (3), disagree (2) and strongly disagree agree (1). Analysis of student and teacher response questionnaires with the aim of knowing responses after using the Socio Scientific Issues (SSI) based global warming e-module to improve students' critical thinking skills and sustainability awareness.

**Result and Discussion**

The development of the global warming e-module follows the stages of Analysis, Design, Development, Implementation and Evaluation which are explained as follows.

*Analysis Stage*

The analysis carried out in the initial stages of the research was analysis of teaching material needs, analysis of student characteristics, and analysis of learning materials.

*Analysis of Teaching Material Needs*

Based on the results of interviews about SSI with 6 teachers at SMA Negeri 3 Cibinong in Bogor Regency, it was found that implementing SSI is important to overcome various environmental problems that are currently occurring. The interview results show that the development of SSI-based e-module teaching materials is needed to facilitate the implementation of SSI because e-modules are usually equipped with pictures, videos and animations to attract students' attention, so that students will be motivated to implement what is

expected in education for sustainable development by acquire the knowledge, skills, attitudes and values necessary to shape a sustainable future. The teacher said that currently, classroom learning still uses teaching materials in the form of books provided by the government. Apart from that, it was found that all said that printed teaching materials had many limitations. These limitations include the tendency to be easily damaged, images that are not clear, and if there is a lot of material, printed teaching materials will require a lot of paper and ink. Interviews with several students said that currently, learning uses teaching materials in the form of books. Printed teaching materials are considered to have many limitations and electronic teaching materials are preferred compared to printed teaching materials. Most people think that electronic teaching materials are more practical to use compared to printed teaching materials. Students also think that the teaching materials currently used need to be further developed to further increase learning motivation. The use of electronic teaching materials is considered more accessible to students. This is because nowadays, the technology to access electronic teaching materials is available, so students can access teaching materials anywhere, anytime, using gadgets, which is easy. The development of information technology allows the development of learning in changing the presentation of teaching materials, in this case printed modules, into modules in digital format or known as electronic modules (e-modules).

*Analysis of Student Characteristics*

Based on the results of preliminary tests on 38 students at public high schools in Bogor Regency, it was found that the average score of students' critical thinking skills was 19.01%. This shows that the level of students' critical thinking skills is still in the low category so they must be improved. Students who answered correctly in aspects of critical thinking skills such as aspects of Elementary Clarification, Advance Clarification, Inference, Basic Support and Strategy and Tactics respectively 12.28% each; 13.16%; 10.53%; 7.89%; and 13.16%. In all aspects, on average, students answered without proper reasons. This shows that students' critical thinking skills need to be improved. The description above indicates the need for innovation in science learning so that learning can achieve its goals. One innovation that can be implemented is SSI-based learning. SSI-based learning connects with current environmental issues, namely Socioscientific Issues (SSI). SSI creates contextual learning conditions to provide opportunities to develop critical thinking skills, argumentation, explore issues, develop moral reasoning and reflective judgment abilities (Kinskey & Zeidler, 2021).

Based on the results of observations regarding sustainability awareness from 52 public high school students in Bogor Regency, it was found that sustainability practice awareness showed that the percentage of students who agreed and strongly agreed was 56.73%. This can be interpreted as meaning that students rarely carry out sustainable actions or practices or sustainability practice awareness. In the category of caring for the environment or behavioral and attitude awareness it is 69.53%. This means that students often or even always do it. In the category of emotional awareness or emotional concern for the environment, it was 76.73%, which means that emotionally students have a high sense of concern for the environment around them. Therefore, efforts need to be made to familiarize students with sustainability practice awareness. Sustainability awareness should be built from an early age because it is very important to support sustainable development.

*Analysis of Learning Materials*

Climate change or what is known as Climate Change is one of the SSI topics. Global warming is in accordance with the learning material in the Independent School Curriculum for Class tackling global warming.

*Design Stage*

The stage for designing interactive multimedia included two stages; the first step was to create flowcharts, and the second was to create storyboards. Making flowcharts is carried out to illustrate the flow of the learning process using interactive multimedia, making it easier to prepare storyboards, plan learning to be carried out and develop e-module in general.

*Development Stage*

The third stage is the development stage. At this stage, the e-module design that has been created is realized. The results of e-module development can be seen in Figures 2.

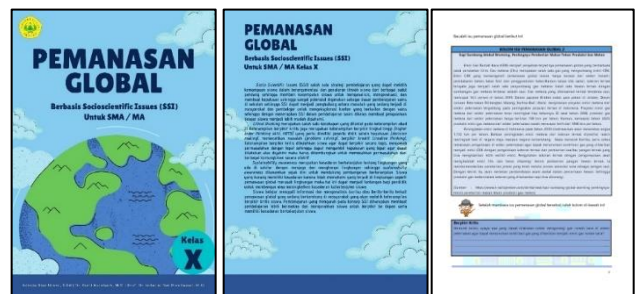


Figure 2. E-Module Front Cover, SSI E-Module Column and E-Module Back Cover

Product validity testing is carried out using assessment sheets given to material and media experts to assess product suitability. The results of the experts' assessments are presented in Tables 1 and 2.

**Table 1.** Expert Judgment Assessment of the Feasibility of the E-module

Expert Judgment	Total Score	Total Score	Percentage	Qualification
Expert 1	84			
Expert 2	97	364	91%	Valid
Expert 3	97			
Expert 4	86			

Based on the results of expert judgment data processing regarding the suitability of the e-module (aspects of suitability of content, suitability of presentation, and suitability of language), a percentage of 91% was obtained. Based on the qualifications from Table 1 of the eligibility level qualifications, the e-module is declared valid from the feasibility aspect (content, presentation and language). Aspects of appropriateness of content include suitability for global warming material as well as suitability for learning objectives. Aspects of feasibility of presentation include component completeness and component clarity. Aspects of language appropriateness include conformity with PUEBI (General Guidelines for Indonesian Spelling) as well as the use of language that is clear and easy to understand.

**Table 2.** Expert Judgment Assessment of Media Aspects

Expert Judgment	Total Score	Total Score	Percentage	Qualification
Expert 1	75	145	97%	Valid
Expert 2	70			

Based on the results of expert judgment data processing on media aspects, a percentage of 97% was obtained. Based on the qualifications from Table 2 of the eligibility level qualifications, the e-module is declared valid from the Media Aspect. The media aspects assessed include usability, functionality and visual communication.

*Implementation Stage*

Implementation is carried out by providing revised e-modules to students in the learning process as teaching materials. Implementation was carried out on a limited basis at SMA Negeri 3 Cibinong for 38 class X students. Before implementing the e-module, students first took a pre-test on critical thinking skills and a sustainability

awareness questionnaire. Implementation of the e-module was carried out in three meetings or 6 class hours. Learning is carried out in class X-11.

Students carry out teaching and learning activities following the learning process design that has been created. The SSI-based global warming e-module used by students includes global warming material, various questions adapted to SSI indicators to improve critical thinking skills and sustainability awareness, formative tests as well as material summaries and bibliography. After completing the learning process, students are given post test questions on students' critical thinking skills and sustainability awareness after using the e-module.

**Tabel 3.** Paired Samples Test

		t	df	Sig. (2-tailed)
Pair 1	pre test post test	-52.325	37	.000

Table 3 shows the Sig value. (2-tailed) is 0.000 < 0.05, so it can be concluded that there is an average difference between the pre-test and post-test results of critical thinking skills, which means there is an influence of the implementation of SSI-based e-modules in improving students' critical thinking skills.

**Table 4.** N-Gain Critical Thinking Skills

Aspects of Critical Thinking Skills	N-Gain	Category
Elementary Clarification	0.95	Tall
Basic Support	0.78	Tall
Inference	0.72	Tall
Advance Clarification	0.78	Tall
Strategy and Tactics	0.68	Currently
Average N-Gain	0.78	Tall

Analysis of students' critical thinking skills shows an average of 0.78, which means the N-Gain score is in the high category. Of the five aspects tested, there are 4 aspects that are in the high category and one aspect that is in the medium category. These four indicators support a high average of students' critical thinking skills. Several things that support students' critical thinking skills include active learning and problem-based learning strategies and models because they refer to a scientific approach (Ulfa & Munastiwi, 2021). Apart from that, the interaction between teachers and students is also influential because teachers need to pay attention to students' thinking processes so that they do not stop or go off track another influencing factor is the student's learning style.

The next evaluation step is an analysis of the second e-module development objective, namely increasing students' sustainability awareness.

**Table 5.** Paired Samples Test

		t	df	Sig. (2-tailed)
Pair 1	pre test post test	-28,058	37	,000

Table 5 shows the Sig value. (2-tailed) is 0.000 < 0.05, so it can be concluded that there is an average difference between the results of the pre-test and post-test on students' sustainability awareness, which means that there is an influence of the implementation of the SSI-based e-module in increasing students' sustainability awareness.

**Table 6.** Average N-Gain Sustainability Awareness Questionnaire

Aspect	N-Gain	Percentage
Sustainability Practice Awareness	0.45	Currently
Behavioral and Attitude Awareness	0.42	Currently
Emotional Awareness	0.48	Currently
Average N-Gain	0.45	Currently

Analysis of students' sustainability awareness shows an average of 0.78, which means the N-Gain score is in the medium category. This shows that overall, there is an increase in students' sustainability awareness before and after learning using SSI-based e-modules. This is because learning using SSI-based e-modules makes students aware of the importance of learning that leads to SSI, which is expected to make learning more meaningful and direct students to think ahead and have sustainability awareness (Salsabila et al., 2019).

The final evaluation step in the module development stage is analyzing the results of student responses to the e-module which has been used as a source of teaching materials. Student responses to the e-module were obtained by giving questionnaires to 38 students with a score range of 1-5.

Table 7 shows that students responded very well to the e-module both in terms of material, appearance, motivation and understanding, amounting to 91%. Students are active in the learning process using e-modules and this can be because the e-modules developed are tailored to student needs based on observation results such as the need for teaching materials that can be accessed easily and can be studied independently (Ningsih & Mahyuddin, 2021). Apart from that, the e-module is also equipped with pictures and videos so that it can increase students' motivation to learn. E-modules can be compiled with multimedia

applications because they can combine various media in the form of text, images, graphics, music, animation, video and interactions into digital files and are used to convey messages to users (Widiana & Rosy, 2021). In addition, the amount of teaching time can be reduced and the learning process can be carried out anywhere and at any time by students independently with e-modules (Tekin et al., 2020).

**Table 7.** Student Responses to the E-Module

Aspect	Total Score	Percentage	Criteria
Material Aspects	884	93	Very good
Display Aspects	1028	90	Very good
Motivational Aspects	696	92	Very good
Aspects of Understanding	172	91	Very good
Average Percentage		91	Very good

Students learn to dig up information and criticize issues or news related to global warming that are currently developing in society (Solli et al., 2018). The process of extracting information and criticizing global warming issues or news will train students' critical thinking skills (Kurniasih et al., 2020). By using SSI-based e-modules, students are more active in solving problems around them (Martini et al., 2021). SSI is a representation of issues or problems in social life which are conceptually closely related to science (Herman, 2018) with relative or uncertain answer solutions.

Based on the results of the article review that has been carried out, it was found that reconstructing teaching materials in the context of socio-scientific issues regarding food additives used in learning can increase scientific literacy. This is proven in research (Yerdelen et al., 2018) can improve students' understanding of concepts. then other research says that the socioscientific issue approach has significant advantages and is practical in providing conceptual understanding, this is supported by increased learning outcomes (Zangori et al., 2017).

Learning that supports student productivity involves SSI-based learning, this means that learning a socioscientific issue approach has a positive impact on students' understanding of concepts (Herman et al., 2020). The use of digital flipbook-based E-Modules to facilitate distance learning in high school can increase students' understanding of concepts, where the average score obtained has reached the high category (Sa'diyah, 2021). The use of e-modules can improve junior high school students' mathematical critical thinking skills (Rismayanti et al., 2022).

Educational activities that increase environmental awareness in students of all ages must be carried out.

Sustainability awareness can be built with knowledge and awareness about what should be done or not (Hamid et al., 2017). Awareness is produced through feelings and actions that influence each other (Clarisa et al., 2020). Awareness can be seen from changes in attitudes and behavior after receiving various information (Ottander & Simon, 2021). Increasing environmental awareness is a representation of students' knowledge, attitudes, behavior and skills in solving environmental problems (Salsabila & Ekawaty, 2021). Knowledge is the basis for forming attitudes that can influence behavior. Learning using the ESD-based global warming e-module can improve students' critical thinking skills in the high category with an average score of N-Gain critical thinking skills of 0,77 (Ekamilasari et al., 2021).

## Conclusion

Based on the research results, it can be concluded that the SSI-based global warming e-module is valid/suitable for use in terms of feasibility (content, presentation and language), as well as in terms of media with the percentages respectively being 91% and 97%. The CVI results related to the feasibility of the e-module are 0.99 (valid). Learning using the SSI-based global warming e-module can improve students' critical thinking skills in the high category with an average score of N-Gain critical thinking skills of 0.78. Learning using the SSI-based global warming e-module can increase students' sustainability awareness in the medium category with an average N-Gain sustainability awareness score of 0.45. Student responses to the SSI-based global warming e-module were very good with an average score percentage of 91%.

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## Author Contributions

Conceptualization, S.S., and B.R.; methodology, S.S., and B.R.; software, S.S.; validation, B.R., and S.K.; formal analysis, S.S.; investigation, S.S.; resources, S.S.; data curation, S.S., S.K., and B.R.; writing – original draft preparation, S.S.; writing – review and editing, S.K., and B.R.; visualization, S.S.; supervision, B.R.; project administration, S.S.; funding acquisition, S.S. All authors have read and agreed to the published version of the manuscript.

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## Conflicts of Interest

The authors declare no conflict of interest

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