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Climate change e-module based on socio-scientific issues teaching and learning: A validity and practicality study

Moh. Usamah*, Fatchur Rohman, Mimien Henie Irawati Al Muhdhar

Faculty of Mathematics and Natural Sciences, State University of Malang, Indonesia

* Corresponding author: moh.usamah.2303418@students.um.ac.id

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ABSTRACT

Climate change education is a priority in Indonesia's national curriculum. One challenge in teaching climate change in biology classes is the limited availability of teaching materials that cover various socio-scientific issues. Further development of these teaching materials is needed. This study aimed to develop a Climate Change E-Module based on Socio-Scientific Issues Teaching and Learning (SSI-TL) and test its validity and practicality in the learning process. This Research and Development (R&D) study used the Lee & Owens model, which focuses on developing multimedia-based learning designs. The e-module was created using Google Sites. Subject matter experts, media experts, and biology education practitioners assessed the e-module's validity. Practicality was assessed based on student responses through one-to-one trials, small group trials, and field trials. The validity test results showed the e-module to be highly valid, with percentages of 93% from a subject matter expert, 94% from a media expert, and 96% from a biology education practitioner. Practicality test results showed a highly practical category, with percentages of 87% for the one-to-one trial, 92% for the small group trial, and 93% for the field trial. Thus, the Climate Change E-Module based on SSI-TL is valid and practical for use in biology education.

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INTRODUCTION

Climate change is a serious phenomenon whose impacts can be felt around the world, including in Indonesia. According to a report from the World Bank Group & Asian Development Bank (2021), Indonesia ranks third among countries with the highest number of disasters due to climate change risks. These disasters are becoming increasingly likely due to a lack of understanding about the urgency of the climate crisis, particularly among younger generations (Andersson et al., 2022; Ratinen, 2021). A national study by Martha et al. (2025) found that

49.7% of Indonesian teenagers have limited knowledge of climate change. This underscores the importance of educating the younger generation about climate change. Currently, there are increasing opportunities to optimize this with the establishment of climate change education as one of the three priority issues in Indonesia's national curriculum (Wahyudin et al., 2024; Sekarwulan et al., 2024).

Climate change education is one effort to equip the younger generation with the knowledge and awareness necessary to take action. The existence of an independent curriculum that prioritizes climate change education in formal schools offers hope for the future (Tang, 2024). However, research by Kundariati et al. (2025a) reveals a gap between teachers' optimism about teaching climate change in biology classes and the limited learning resources available in secondary schools. One solution is to provide adequate teaching materials (Ben Zvi Assaraf et al., 2025). These materials can be designed as digital media, aligning with current learning resource developments that leverage technology's flexibility (Haleem et al., 2022). This approach aligns with research by Putri et al. (2024) in Indonesian schools, which revealed that most teachers and students agree on the importance of using interactive digital media for biology education.

One type of digital teaching material that can optimize climate change education is the e-module. E-modules offer advantages in terms of practicality, flexibility, and interactivity, motivating students to use them in class or elsewhere without time restrictions (Dewi et al., 2022). The characteristics of e-modules, including self-instruction and self-containedness, make them very suitable for climate change content that needs to be presented in its entirety and can be used by students in independent learning (Silalahi et al., 2024). Involving e-modules in learning can also support students' empowerment in problem-solving and environmental literacy (Eldis et al., 2024; Watoni et al., 2022).

The importance of using e-modules in climate change education is based on the results of a needs assessment in schools. A needs assessment was conducted through interviews with two biology teachers at SMAN 8 Malang. The results showed that the climate change teaching materials used so far have never involved e-modules. Students today are considered tech-savvy, so using e-modules can spark their interest in continuing to learn using digital devices. This aligns with research by Szymkowiak et al. (2021), which shows that today's students prefer new learning patterns that use technology because they generally provide flexible, interactive multimedia content. Additionally, according to Haleem et al. (2022) technology can increase student engagement, making learning more dynamic and interesting.

E-modules have been widely implemented in learning through the integration of problem-based learning models (Febriana & Kartijono, 2023; Nurissamawati et al., 2024). For multidisciplinary issues such as climate change, the learning model should be both problem-based and accommodate learning crosscutting concepts. This aligns with Eilam's (2022) assertion that climate change requires a cross-disciplinary approach, which can only be meaningfully understood by integrating science with non-science disciplines. Sjöblom et al. (2023) state that climate change is a socio-scientific issue (SSI) because it represents the interconnection between science and society regarding complex, controversial, and far-reaching problems. Therefore, a Climate Change E-Module based on an SSI-oriented learning model is necessary.

The Socio-Scientific Issues Teaching and Learning (SSI-TL) model is one learning model that can be integrated with the Climate Change E-Module. SSI-TL is advantageous because it aligns with the Next Generation Science Standards (NGSS) framework, which emphasizes three-dimensional science learning: disciplinary core ideas (DCIs), crosscutting concepts (CCCs), and science practices (SPs) (National Research Council, 2012). SSI-TL consists of three stages: encountering the focal issue, three-dimensional science learning, and synthesis of ideas and practices (Sadler et al., 2016). These learning stages can serve as the primary design for developing the e-

module so that students focus on problem-solving from various perspectives. This approach aligns with Högström et al. (2024) that SSI content should be incorporated into various topics related to current issues using teaching models that align with evolving educational practices, including integration with digital teaching materials.

The Climate Change E-Module, which has been developed, also needs to be tested for validity and practicality before being implemented in the learning process. Validity testing ensures the content of the e-module is accurate, suitable, and consistent with current standards. Practicality testing confirms that the e-module is user-friendly and appealing to students (Akker et al., 2013). Dahal et al. (2023) state that a learning product is suitable for use if its content is proven valid and its application is proven practical. Various studies on e-module development have conducted validity and practicality tests to ensure their suitability for the learning process (Fauzi & Habibah, 2025; Marlina et al., 2025; Nasution & Anas, 2025). Therefore, validity and practicality tests are essential to ensure that the climate change e-module is relevant and functional and has a positive impact on students' learning.

This study aims to develop and test the validity and practicality of the Climate Change E-Module Based on SSI-TL as an interactive teaching material for biology. Theoretically, this study contributes to the strengthening of research on developing digital learning media based on SSI-TL, which can improve the quality of the learning process and outcomes for students. In practice, the results of this study will be useful for teachers as valid, easy-to-use teaching materials for climate change concepts and for students as attractive, contextual learning tools that encourage problem-solving skills and environmental awareness.

RESEARCH METHODS

Research Design

This research is a type of research and development (R&D). The R&D model used is the Lee & Owens model (2004), which focuses on developing multimedia learning designs. The model consists of five stages: analysis, design, development, implementation, and evaluation.

Population and Samples

This study's population consisted of all subject matter experts, media experts, biology education practitioners, and students at SMAN 8 Malang. The sample was determined using purposive sampling based on empirical considerations, including participants' expertise, experience, and relevance to the study objectives. The validity test involved three validators: one subject matter expert who is a lecturer in Geography Education at Universitas Negeri Malang with expertise in climate change education studies; one media expert who is a lecturer in Chemistry Education at Universitas Negeri Malang with expertise in digital media development; and one biology education practitioner who is a Grade X biology teacher at SMAN 8 Malang. The sample for the practicality test consisted of 43 grade XI students at SMAN 8 Malang.

Instruments

The validity of climate change materials is assessed using the Material Expert Validation Sheet, which covers content requirements, content suitability, presentation standards, and language standards. The validity of e-module media is evaluated with the Media Expert Validation Sheet, which addresses design, graphics, and e-module characteristics. The validity of the e-module is measured using the Biology Education Practitioner Validation Sheet, which includes aspects of content suitability, presentation, language, design, graphics, and usability. Meanwhile, the Student Response Questionnaire, consisting of 17 items related to the ease of use and attractiveness of the

e-module, is used to assess its practicality. All items in the validity and practicality instruments employed a 5-point Likert scale.

Procedures

This research procedure consisted of four stages: analysis, design, development, and evaluation. The analysis stage involved conducting a needs assessment at schools to identify learning problems and requirements for climate change materials. The design stage included preparing the research schedule, determining the research team, and outlining the e-module structure. The development stage covered the creation of a storyboard to organize the content flow and the assembly of the e-module using the Google Sites platform. The evaluation stage included validity and practicality tests. The validity of the e-module is determined based on assessments by subject matter experts, media experts, and biology education practitioners. Practicality is assessed through one-to-one trials with three students, small group trials with ten students, and field trials with thirty students.

Data Analysis

The data were analyzed using quantitative descriptive analysis techniques to test the validity and practicality. The scores for each instrument item using a 5-point Likert scale were added up, then the percentage value was calculated using the following formula:

$$Percentage = \frac{Score\ obtained}{Maximum\ Score} \times 100\%$$

This formula was used to determine the level of validity and practicality by converting the total scores into percentage values. The percentage results are converted into validity and practicality categories to make a final decision based on the following criteria (Table 1).

Table 1. The categories of validity and practicality

Percentage	Categories of Validity and Practicality
100	Highly Valid/Practical: Product can be used without revision
$85 \leq X \leq 99$	Highly Valid/Practical: Product can be used with minor revisions
$70 \leq X < 85$	Valid/Practical: Product can be used with moderate revisions
$55 \leq X < 70$	Less Valid/Practical: Product can be used with major revisions
$40 \leq X < 55$	Not Valid/Practical: Product cannot be used
$X < 40$	Highly Invalid/Impractical: Product cannot be used

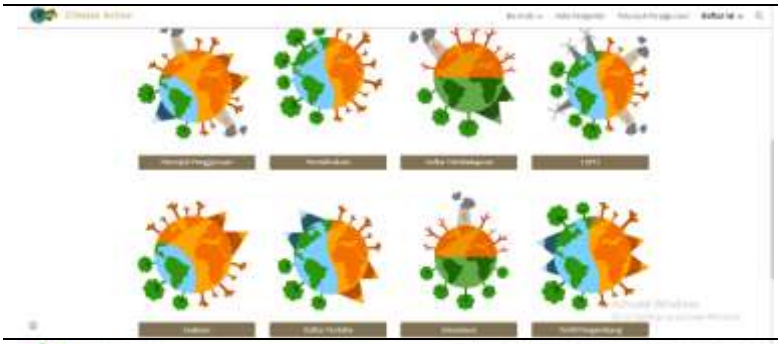
RESULTS

Results of Developing the Climate Change E-Module

The result of this research is a Climate Change E-Module based on SSI-TL and integrated into Google Sites. Table 2 presents an overview of the e-module development results. Based on Table 2, the e-module is structured with essential climate change material designed according to the SSI-TL stages and supported by various interactive features. The e-module's structure consists of a home page, an introduction, instructions for use, a table of contents, a learning list, student worksheets, an evaluation, a bibliography, a glossary, and developer profiles. The presented climate change material includes basic concepts of climate stability and change, factors causing climate change, the impact of climate change on life, and climate change mitigation and adaptation. The

SSI-TL stages include encountering the focal issue of climate change at the beginning of each sub-topic, three-dimensional science learning (explanation of sub-topic concepts, observational simulations with external platforms, and studies of causes and impacts), and synthesis of ideas and practices through activities in the student worksheets. The e-module contains multimedia elements, such as articles, images, videos, graphics, and external platforms, to support the explanation of climate change content.

Table 2. Results of the Climate Change E-Module Development

Climate Change E-Module Display	Description
	The home page displays the title of the e-module and the subject it covers. In the top right corner, there are navigation links to the introduction, instructions for use, and table of contents. An image related to climate change is displayed in the background of the home page.
	The Table of Contents page lists the structure of the e-module, ranging from usage instructions to developer profiles. It is equipped with navigation buttons that lead to the desired page.
	The introductory page contains a description of the e-module, its rationale, and its relevance, as well as the learning outcomes. Buttons have also been added to navigate to related pages.
	The Learning List page contains the chapter structure for climate change. There is also a concept map for Climate Change at the bottom of the page. Each chapter begins with learning objectives, material descriptions, and introductory learning videos.

Climate Change E-Module Display	Description
	The opening page of each chapter of the learning material contains videos and articles that introduce socio-scientific issues. This represents the first stage of SSI-TL: encountering focal issues.
	Each chapter of the learning material contains an external platform with simulations or digital practices related to the concepts covered in the material. These simulations represent the second stage of SSI-TL: three-dimensional science learning.
	The student worksheets page contains student activity sheets that can be downloaded and collected via a link to Google Drive. The activities in the student worksheets are problem-solving-based activities that represent the third stage of SSI-TL: synthesis of ideas and practices.

Results of the validity test for the Climate Change E-Module

Subject matter expert validation yielded an average percentage of 93%, classified as highly valid with minor revisions (Table 3). Based on the subject matter validators' suggestions, revisions were made to improve the quality of the climate change material presented in the e-module (Table 4). After the revisions, the subject matter experts concluded that the e-module contained highly valid material, making it suitable for use in the learning process.

Table 3. Results of subject matter expert validation

No.	Aspect	Average Score	Percentage	Category
1.	Content Requirements	4,8	96	Highly Valid
2.	Content Suitability	4,6	92	Highly Valid
3.	Presentation Standards	4,6	93	Highly Valid
4.	Language Standards	4,4	88	Highly Valid
	Average	4,6	93	Highly Valid

The media expert validation results obtained an average percentage of 94%, which is classified as "highly valid" with minor revisions (Table 5). Based on the media validators' suggestions, revisions were made to improve the appearance and media in the e-module (Table 6).

After the revisions, the media experts concluded that the e-module had highly valid media quality, making it suitable for use in the learning process.

Table 4. Revision suggestions from subject matter expert.

No.	Revision Suggestions
1.	References must be added from field observations or research journal articles.
2.	The concept of ecosystem material must be supplemented with the mechanisms that occur within it. Similarly, natural factors need to be added to the list of factors causing climate change.
3.	The material on basic climate concepts is organized in a more logical sequence. For example, it first explains the meanings of weather and climate, and then discusses the role of ecosystems in climate stability.
4.	Some of the supporting images are not representative because they do not show where the events depicted in them took place.

Table 5. Results of media expert validation

No.	Aspect	Average Score	Percentage	Category
1.	Design	4,6	93	Highly Valid
2.	Graphic	4,7	93	Highly Valid
3.	Characteristics of E-Modules	4,7	95	Highly Valid
	Average	4,7	94	Highly Valid

Table 6. Revision suggestions from a media expert

No.	Revision Suggestions
1.	The menu on the home page should be arranged sequentially: Home > Introduction > Instructions for Use > Table of Contents.
2.	The concept map should be clear, not blurry.
3.	Pages that are too long should be redesigned to fit on one page. If the page exceeds one page, a "Next" button should be added.
4.	The pretest and posttest displays should have icons that link to Google Forms instead of linking to them directly. The icons should link to Google Forms.
5.	Every term in the glossary should link to the relevant section of the text.
6.	The front page of each topic has an imbalanced layout of the banner and text. A better composition is needed. The banner can be adjusted according to the requirements for the image and title.
7.	An introductory video from the developer should accompany each material so that students who access it feel as if they are with their teacher.

The validation results by biology education practitioners obtained an average percentage of 96%, which is classified as "highly valid" with minor revisions (Table 7). Revisions were made based on the practitioners' suggestions to improve the e-module's quality (Table 8). The researchers considered the practitioners' suggestions regarding SSI-TL testing of other materials as a possibility for future studies, as this was outside the scope of this study. After revisions were made, the biology education practitioners concluded that the e-module has highly valid material and media quality, making it suitable for use in the learning process.

Table 7. Results of validation by biology education practitioners

No.	Aspect	Average Score	Percentage	Category
1.	Kelayakan Isi Materi	5,0	100	Highly Valid
2.	Penyajian	4,9	98	Highly Valid
3.	Bahasa	4,6	92	Highly Valid
4.	Desain dan Grafika	4,6	91	Highly Valid
5.	Kegunaan	4,6	92	Highly Valid
	Average	4,7	96	Highly Valid

Table 8. Revision suggestions from biology education practitioners.

No.	Revision Suggestions
1.	The video link in the student worksheets should be shortened for easier access.
2.	The e-module should be supplemented with scientific articles on local environmental issues.
3.	The SSI-TL model should be tested on topics other than climate change to evaluate its effectiveness.

Results of the Practicality Test for the Climate Change E-Module

The results of the practicality test averaged 91%, which is classified as "very practical" with minor revisions. The details of the practicality test include a one-to-one trial with three students (87%), a small group trial with ten students (92%), and a field trial with thirty students (93%) (Table 9). Overall, the results show that the Climate Change E-Module is very practical. Most students responded positively to the e-module because of its attractive appearance, comprehensive content, numerous supporting images and videos, and variety of information on actual climate change phenomena. Thus, the e-module is practical, making it suitable for use in the learning process.

Table 9. Result of the practicality test

No.	Aspec	Average Score	Percentage	Category
1	One-to-One Trial	4,4	87	Very Practical
2	Small Group Trial	4,6	92	Very Practical
3	Field Trial	4,7	93	Very Practical
	Average	4,5	91	Very Practical

DISCUSSION

Development of Climate Change E-Module

The Climate Change E-Module, created using Google Sites, offers various interactive features to support the learning process. The availability of multimedia elements, such as articles, images, videos, and graphics, as well as external platforms that support concept explanations, can accommodate differentiated learning and provide students with a more optimal learning experience. Interacting with various website elements provides an interactive learning experience for students (S et al., 2025). Navigation buttons provide an interactive experience that helps students navigate to the desired page more flexibly (Kusumawati et al., 2021). The use of these various interactive features aligns with the research by Wicaksono et al. (2023), which concluded that Google Sites has advantages in terms of quick and easy accessibility, no cost, no need for special programming skills, and a variety of interesting tools that support the learning process.

The Climate Change E-Module contains essential sub-material covering the basic concepts of climate stability and change, the factors causing climate change, the impact of climate change on life, and climate change mitigation and adaptation. This is in line with the climate change education framework recommended by Teixeira & Crawford (2022), which should at least cover the causes, impacts, mitigation, and adaptation of climate change. The basic concepts of climate stability and change are added as a foundation of knowledge for students, which also includes material on ecosystems. Ecosystem material is considered important to study because the causes, impacts, and solutions to climate change are closely related to ecosystems (Canadell & Jackson, 2021). At the beginning of each sub-topic, information about the learning objectives is also presented. The presentation of learning objectives can provide clear information to students regarding learning activities and the requirements that must be achieved (Orr et al., 2022). The flow of the sub-material discussion is also presented in the form of a concept map. Anastasiou et al. (2024) mention that concept maps can present material concepts concisely, making it easier for students to understand the interrelationships between the concepts to be studied.

Integrating SSI-TL into the Climate Change E-Module provides structured learning activities that strengthen understanding of the context and concepts necessary for formulating solutions to climate change problems. By encountering actual focal issues of climate change and various scientific case studies, students learn to identify climate change problems and become more responsive in their attitudes and actions to solve them. This aligns with the research by Toogood (2025), which states that applicable and relevant case studies support effective student engagement with the potential to increase awareness. Three-dimensional science learning, which involves disciplinary core ideas, cross-cutting concepts regarding causes and effects, and a platform for science practice, is also suitable for the complex concept of climate change. This approach develops students' in-depth understanding of the interrelationships between concepts (Kaldaras et al., 2021). Understanding the context of the problem and the material concepts leads students to synthesis ideas and practices by formulating solutions to climate change problems in everyday life (Kundariati et al., 2025b). This entire process is contained within the activities outlined in the student worksheet linked to the e-module.

Validity of Climate Change E-Module

The validity of the Climate Change E-Module material demonstrates its very high quality in terms of content, presentation, and language, making it suitable for learning purposes. The climate change material is considered suitable due to its comprehensive coverage and compliance with applicable curriculum requirements. Its completeness and suitability can help students grasp the concepts as a whole (Nikmah & Zuleha, 2025). The material is based on relevant references from journal articles, which support the author's credibility (Lubis et al., 2023). The images presented to support the explanations are also relevant. These images can provide significant meaning to the text being explained (Rehman et al., 2022). The language used to deliver the material has been adapted to the characteristics of Phase E students. This aligns with the statement by Sodiq et al. (2024), that teaching materials must use appropriate, communicative language according to students' developmental and linguistic proficiency levels.

Media validity demonstrates that the Climate Change E-Module has a valid design, suitable graphics, and appropriate characters. The typography, including font, color, and layout, is visually appealing, thereby strengthening the meaning of the text, increasing its appeal, and promoting the effectiveness of the e-module's design and communication (Günay, 2024). The menu design of the e-module on the homepage and in the table of contents is structured to help students understand how to use it (Beege et al., 2023). Each page is proportionally sized so students won't get bored scrolling through text that is too long. This aligns with the statement by Keskinkılıç & Karataş

(2023), that neat and proportional text structure makes the text easier to digest, so students can focus on content without getting tired quickly. The e-module has also been designed with user-friendly characteristics in mind. For example, the glossary contains links to the pages where the terms are found, allowing students to access them without manually searching other sections (Li et al., 2023).

Based on the feedback of biology education practitioners, the material, media, and usefulness of the Climate Change E-Module are considered to be of very high quality. The introductory video by the researcher is considered to represent an instructor's presence in learning through e-modules. This is in line with the statement by Ingram et al. (2024) that short videos from instructors in digital media can give the impression of presence, which builds emotional connections and increases student motivation in learning. The student worksheets linked to the e-module adhere to the SSI-TL syntax so students can solve climate change problems through the learning process. The e-module has practical applications, such as using Google Drive to collect student worksheets and Google Forms to administer pre-test and post-tests. Using Google Drive in the learning process can facilitate collaboration between teachers and students (Tukur et al., 2021), and using Google Forms can help teachers effectively manage and assess learning (Lim et al., 2023).

Practicality of Climate Change E-Module

Based on the results of one-to-one trial, small group trial, and field trial, the practicality of the Climate Change E-Module shows that it is very useful for learning. Student responses regarding the e-module's practicality are positive. Students said the e-module has an appealing appearance that attracts their attention. This aligns with the research by Sun & Pan (2021), which states that applying technology to learning can motivate students and improve learning effectiveness. The Google Site e-module format is easily accessible on various electronic devices, making it adaptable to today's technological era (Nugraha, 2024). Adaptive e-modules can accommodate inclusive and sustainable education in an ever-evolving digital era (Chairad et al., 2025). The e-module content is considered comprehensive due to its abundance of images, videos, and news texts supporting the learning material. Multimedia completeness in e-modules enables more interactive learning, which can improve students' understanding and interest in learning (Junaedi et al., 2022).

The practicality of the Climate Change E-Module is supported by external platforms that provide science resources and present various issues to raise students' awareness of climate change. One external platform is the Physics Education Technology (PhET), which offers simulations of greenhouse gases. E-modules supported by the PhET platform can improve students' understanding by using dynamic visualizations to explain abstract concepts, such as the greenhouse effect (Ulfa et al., 2024). Presenting various issues in the form of articles and videos also raises students' awareness of climate change and its impact on life. This is in line with the research by Dunne et al. (2022), which shows that the use of e-modules with multimedia-based content can improve students' understanding of climate change concepts and their awareness of sustainability issues. Students' responses indicate that e-modules have the potential to motivate independent learning. This aligns with research by Sidauruk et al. (2025) showing that practical e-modules encourage independent learning and improve learning outcomes.

CONCLUSION

The Climate Change E-Module based on SSI-TL contains essential climate change material and learning activities based on the SSI-TL stages. These activities are supported by various interactive features through Google Sites. Validity testing by a subject matter expert, a media expert, and a biology education practitioner shows that the e-module is highly valid. Practicality test results, based on student responses from one-to-one, small group, and field trials, also

demonstrate the high practicality of the e-module. These findings confirm that a valid and practical e-module can enhance interactive learning and improve students' understanding of climate change. Further research could explore its effectiveness in developing students' climate change competencies.

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