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Development of gamification-based e-module on global warming material for grade X

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Abstract

Although electronic modules offer interactivity, the integration of gamification remains limited, particularly for topics such as global warming in high school biology. This gap highlights the need for teaching materials that align with the demands of the digital era and the characteristics of modern learners. This study aims to develop a gamification-based e-module on global warming, determine the feasibility of the developed e-module, and assess student responses. This research is of the Research and Development (R&D) type using the 4D model, limited to the development stage. The instruments used in this study include interview sheets and environmental literacy questions in the define stage, the e-module design blueprint in the design stage, content feasibility validation sheets, graphic design and language validation sheets, as well as student response questionnaires in the development stage. The results of this research are as follows: (1) the feasibility of the gamification-based e-module in terms of content has a score of 85.49, categorized as "very feasible," (2) the feasibility in terms of graphic design has a score of 91.16, categorized as "very feasible," (3) the feasibility in terms of language has a score of 87.27, categorized as "very feasible," (4) the average student response score is 91.11, with 89% of students giving a positive response to the e-module, and (5) the gamification-based e-module on global warming is highly feasible to be used in the learning process. This study has both theoretical and practical implications. Theoretically, the gamification-based e-module opens opportunities for the development of more interactive learning materials that can enhance environmental literacy and learning motivation. Practically, this e-module serves as an engaging alternative in science education, particularly in biology, and can be further developed by teachers for various subjects and educational levels.

Abstrak. *Meskipun modul elektronik menawarkan interaktivitas, integrasi gamifikasi masih terbatas, terutama untuk topik seperti pemanasan global dalam biologi SMA. Kesenjangan ini menyoroti kebutuhan akan bahan ajar yang sesuai dengan tuntutan era digital dan karakteristik pembelajar modern. Penelitian ini bertujuan untuk mengembangkan e-module berbasis gamifikasi pada materi pemanasan global, mengetahui kelayakan dari e-module yang dikembangkan dan respon peserta didik. Jenis penelitian ini adalah Research and Development (R&D) dengan menggunakan model 4D yang dibatasi hanya sampai pada tahap development. Instrumen pada penelitian ini adalah lembar wawancara, lembar validasi kelayakan isi materi, kegrafikan dan bahasa serta angket respon. Hasil penelitian yaitu; (1) kelayakan e-module berbasis gamifikasi pada aspek kelayakan isi adalah 85,49 dengan kategori "sangat layak", (2) kelayakan pada aspek kegrafikan mendapatkan nilai 91,16 dengan kategori "sangat layak", (3) kelayakan pada aspek bahasa sebesar 87,27 dengan kategori "sangat layak", (4) nilai rata-rata respon peserta didik yaitu sebesar 91,11 dengan 89% peserta didik memberikan respon positif terhadap e-module (5) e-module berbasis gamifikasi pada materi pemanasan global sangat layak digunakan dalam proses pembelajaran. Penelitian ini memiliki implikasi baik secara teoritis maupun praktis. Secara teoritis, e-module berbasis gamifikasi membuka peluang untuk pengembangan bahan ajar yang lebih interaktif yang dapat meningkatkan literasi lingkungan dan motivasi belajar peserta didik. Secara praktis, e-module ini berfungsi sebagai alternatif menarik dalam pendidikan sains, khususnya biologi, dan dapat dikembangkan lebih lanjut oleh guru untuk berbagai mata pelajaran dan jenjang pendidikan.*

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A. Introduction

The advancement of information and communication technology (ICT) in recent decades has had a significant impact across various sectors, including education. In today's digital era, the use of technology in learning activities has become an unavoidable necessity. The development of technology in education must align with the progress of the times (Akbar, 2021). Technology plays a vital role in the learning experience and is a major concern for educators, beginning from the planning phase of learning activities to the implementation of teaching and instruction (Altun & Ahmad, 2021; Wang, 2017). Teachers are one of the components that must keep up with this technological development. According to Siswati et al. (2021), teachers have the responsibility to educate students according to the times in which they live. In the teaching process, teachers need to make additional efforts to integrate effective teaching strategies and materials. There are many ways teachers can present appropriate and relevant lessons, one of which is through the use of teaching materials. Teaching materials are crucial for achieving learning objectives, and in order for students to understand the material more easily, the selection of teaching materials becomes a very important aspect of learning. Teaching materials function as essential tools for both educators and learners in reaching instructional objectives, offering content that is both appealing and tailored to the students' circumstances and learning needs (Ritonga et al., 2022). One example of teaching material that utilizes technology and is designed in accordance with the advancement of digitalization in the education sector is the e-module (Delita et al., 2022).

An e-module is a structured learning material presented in an electronic format, complete with animations, audio, and videos, creating an interactive experience between the user and the program. According to Pratiwi et al. (2023), an e-module is one of the electronic versions of teaching materials, designed using specific software or applications as supporting tools. E-modules are highly compatible with the characteristics of students today, who have grown up in the digital era, where the influence of digital technology is deeply embedded in their daily lives (Pratiwi & Indana, 2022). E-modules have several advantages, such as being interactive and equipped with formative quizzes that allow for immediate feedback (Ramadayanty et al., 2021). The text, images, graphics, animations, and videos present in e-modules can attract students' interest and can be accessed anytime and anywhere (Dewi & Lestari, 2020; Fry, 2019; Handayani et al., 2021; Sumarmi et al., 2021). Hapsari et al. (2019) also stated that media such as videos, animations, and motion graphics can enhance students' academic performance. This is important because students can maximize the use of their smartphones, both for self-learning and social interaction. Other benefits include ease of mobility as it does not physically burden the students, more efficient production costs, long-lasting durability without easily being damaged over time, and the ability to integrate audio and video into a single display.

Although many e-modules have been developed to support the learning process, few integrate them with gamification elements. Game-based learning has now become a popular topic in academic literature due to its ability to make learning more enjoyable and increase student motivation to actively engage in the learning process. Gamification in education refers to the use of game design and elements in teaching and learning activities. This approach has been applied to support learning across various subjects and contexts, as well as to address attitudes, activities, and behaviors such as collaboration, self-study, task completion, improving assessment effectiveness, exploring exploratory approaches in learning, and enhancing creativity and memory retention in students (Emlano & Walag, 2023). Integrating game elements into the biology curriculum in secondary schools offers an innovative approach to address the challenges of teaching complex biology concepts while increasing student engagement. By tailoring game elements to the level of difficulty of biology content, educators can enhance student participation, stimulate critical thinking, and create a dynamic learning environment that aligns with the teaching needs of biology at the secondary school level (Lantzouni et al., 2024). Research conducted by Asniza et al. (2021) shows that games can capture students' interest in participating in learning sessions, with a significant increase in engagement and learning achievement. The pedagogical application of gamification in science education has been proven to positively impact students' academic performance (Funa & Ricafort, 2019; Kalogiannakis et al., 2021).

Currently, there is no gamification-based e-module connecting the topic of global warming in the Science curriculum for Grade X in Senior High Schools (SMA/MA). However, global warming is a highly relevant and important topic, especially given the growing need for students to increase their awareness of environmental issues. Understanding global warming is crucial for raising environmental awareness and comprehending the global challenges at hand, which is why the government has decided to include the concept of global warming in the Integrated Science subject for phase E of the Merdeka Curriculum (Anggreni et al., 2020). Based on interviews with Science teachers at a Madrasah Aliyah (MA) in Riau Province, the use of traditional teaching methods, such as lectures, in the global warming topic does not promote active learning, leading to low student engagement due to the teacher's dominance

in the learning process. Additionally, the limited number of printed books in schools makes learning monotonous, and students are less involved in discussions. The available printed books are often outdated, which hinders students from understanding current environmental issues. The abstract nature of global warming, whose effects may not be visible for decades or even centuries, also reduces students' motivation to study it, resulting in a decline in the overall quality of learning and a decrease in their curiosity (Hariyono et al., 2024). Therefore, based on the background presented, this research aims to develop a gamification-based e-module on the topic of global warming. Various previous studies related to the development of gamification-based e-modules have stated that the developed e-modules are suitable for use in the learning process and can improve students' academic performance as well as their learning motivation (Ardianty et al., 2023; Asmianto et al., 2022; Jannah et al., 2020; Pangestu et al., 2019; Puspitasari et al., 2023). The advantage of this research is that the developed e-module is integrated with real games and online games, making it more varied and interactive. As an essential element in sustainable development and competition in the 21st century, this e-module is expected to address challenges related to the need for teaching materials that align with students' needs and the advancement of the times. Quality teaching materials are always adapted to technological advancements, art, and the dynamics of a society that is increasingly globally connected (Pangestu et al., 2019). If teachers do not incorporate technology into their teaching, they risk lagging behind the constantly advancing methods (Zhang, 2022).

B. Material and method

The method used in this research is Research and Development (R&D). Research and Development is a research method widely used in the academic world to design and test the effectiveness of a product (Waruwu, 2024). The model used is the 4D model, which consists of four stages: (1) Define, (2) Design, (3) Development, and (4) Disseminate.

The 4D development model was chosen because it has shorter stages compared to other models while still maintaining a detailed process at each stage. In this research, the development of the e-module was carried out only up to the development stage because the dissemination or distribution of the product has not been conducted as it is still in the refinement stage. The process for each stage can be seen in Figure 1.

The data collection techniques used in this research are literature study, interviews, and questionnaires. The instruments used in this research include interview sheets, e-module validation questionnaires, and student response questionnaires regarding the e-module. A literature study is necessary to gather content and practice questions for the e-module that will be developed and used by students. Interviews were conducted with Science teachers of Grade X at a Madrasah Aliyah (MA) to understand the applicable curriculum, teaching materials used in the school, and the challenges in teaching Science on the topic of global warming. The interview sheet serves as a guide for the researcher to ensure that the questions asked are relevant and aligned with the research objectives. The topics of the questions asked during the interview can be seen in Table 1.

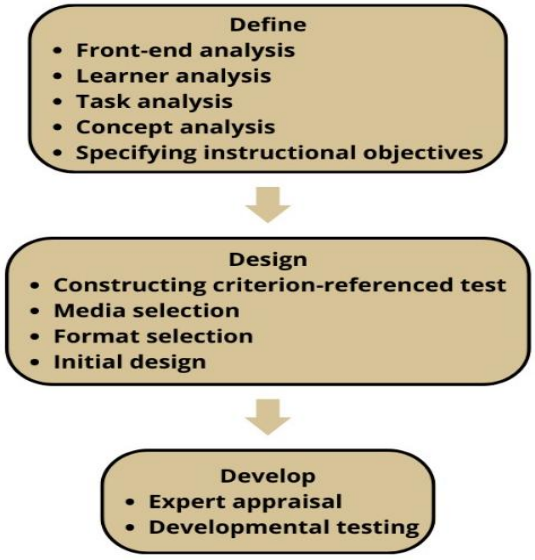

Figure 1
Research stages (Source: Thiagarajan et al., 1974)

In addition to interviews, another data collection technique used is the e-module validation questionnaire. The purpose of using this questionnaire is to evaluate the suitability and relevance of the e-module being developed. The validation of the developed e-module was carried out by expert validators consisting of lecturers and teachers. This assessment was adapted from the components for evaluating the feasibility of the content, graphic design, and language of the module from *Badan Standar Nasional Pendidikan (BSNP)*, using a Likert scale of 1-4: 1) Very Inadequate, 2) Inadequate, 3) Adequate, and 4) Very Adequate. The Likert scale is used to measure attitudes, opinions, and perceptions of an individual or a group of people in relation to the product being produced (Ardianty et al., 2023). Table 2 shows the evaluation indicators for the feasibility of content, graphic design, and language.

The data from the e-module validation assessment obtained from the expert validators were then analyzed using Formula 1 by Purwanto (2008). The results of the e-module validation calculations are then adjusted according to the feasibility criteria as shown in Table 3.

Table 1 Interview question topics with grade X science teachers

No	Question topics
1	The curriculum implemented in the school.
2	The teaching materials used in Grade X Science for the global warming topic.
3	The teacher's opinion on the relevance of the content and the potential of the teaching materials.
4	The use of gamification-based e-modules in the school.
5	Issues faced by the teacher when teaching the global warming topic.
6	Efforts made by the teacher to provide teaching materials that meet students' needs and the advancements of the times.

Table 2 Indicators for e-module feasibility testing

Aspect	Assessment indicators
Content feasibility of the e-module	A. Alignment of the material with the Merdeka Curriculum B. Accuracy of the material C. Currency of the material D. Encouragement of curiosity
Graphic design feasibility	A. Module size B. Cover design C. Content design
Language feasibility aspect	A. Clear B. Communicative C. Dialogical and interactive D. Suitability with student development E. Conformity with language rules F. Use of terms, symbols, or icons

$$N = \frac{k}{Nk} x\ 100\% \dots\dots\dots\dots\dots\dots\dots\dots\dots \text{Formula 1}$$

Description:
N = Percentage on the aspect
k = Value of the aspect
Nk = Value that must be achieved

In addition to the e-module validation questionnaire, this study also used a student response questionnaire to gather students' opinions on the developed e-module. A response is the reaction or impression that a person gets after observing an activity that involves the senses and evaluating an object. The response assessment is still adapted from the components for evaluating the feasibility of the content, graphic design, and language of the module from the BSNP, with evaluation indicators covering material scope, presentation, language, and graphic design, which are elaborated into fifteen statement items using a Likert scale: 1) Strongly Disagree, 2) Disagree, 3) Agree, and 4) Strongly Agree.

$$\text{Student response score} = \frac{R}{SM} \text{x } 100\% \dots\dots \text{Formula 2}$$

Description:
R = Total score obtained
SM = Maximum total score

After obtaining the calculation results from the student response scores using Formula 2, they are then adjusted according to the student response criteria. To determine the criteria for the student response scores, the following criteria, as presented in Table 4, are used.

Table 3 E-module feasibility criteria

Interval %	Criteria
81,26% < N ≤ 100%	Very Feasible
62,51% < N ≤ 81,25%	Feasible
43,76% < N ≤ 62,50%	Adequately Feasible
25% < N ≤ 43,75%	Not Feasible

(Source: Purwanto, 2008)

Table 4 Criteria for student responses

Student response score	Response criteria
76 ≤ Student response score percentage ≤ 100	Positive
56 ≤ Student response score percentage ≤ 75	Moderate
0 ≤ Student response score percentage ≤ 55	Negative

After students are grouped based on the response criteria in Table 4, the next step is to calculate the number of students who provided a positive response. According to Hobri (2009), student responses can be used to assess the achievement of learning objectives if the number of students giving a positive response reaches 80% or more of the total subjects being studied. The percentage of students who provided a positive response can be calculated using the Formula 3.

$$\% = \frac{\text{Number of positive responses}}{\text{Total number of students}} \text{x}100\% \quad \text{... Formula 3}$$

C. Results and discussion

The purpose of this research was to develop an e-module on the topic of global warming. In line with this objective, the study used the Research and Development (R&D) method, adopting the 4D model (Define, Design, Development, Disseminate), which was limited to the Development stage only. The results of the e-module development will be explained in the following three stages.

Define stage of the gamification-based e-module on global warming

The first stage is to define the requirements needed for the development. In the product development process, it is essential to refer to these requirements, analyze them, and gather information on how far the e-module development needs to be carried out. The first step in the definition stage is a front-end analysis, which is conducted to identify and determine the root problems in the learning process, serving as the basis for the need to develop a gamification-based e-module. Through interviews, several issues were identified when teachers taught the topic of global warming (see Table 5). The traditional teaching methods did not promote active learning and led to a decrease in student engagement due to the teacher's dominance in the learning process. Additionally, the teachers' dependence on the available printed books in the school made the learning process monotonous, and there was a lack of student participation in discussions, especially since the number of printed books was limited. There is a need for more varied and easily accessible learning media to engage students with the material and motivate to learn.

Table 5 Interview results with the 10th grade science teacher

Questions	Respondent's answer
What curriculum is currently implemented at the school where you teach?	Currently, the curriculum implemented at the school is the Merdeka Curriculum
What type of teaching materials do you use in teaching science to Grade X students on the topic of global warming?	The teaching material used is a book published by one of the publishers in Indonesia in 2024.
In your opinion, is the teaching material you use relevant to the current curriculum and does it have the potential to enhance students' environmental literacy and learning motivation?	It is fairly relevant, but it still lacks presentation of real facts about global warming. The book is not in color, which may make it less engaging for students.
Have you ever taught the topic of global warming using a gamification-based e-module?	I have never used e-modules in any form during the learning process, including gamification-based e-modules.
What challenges do you often face when teaching the topic of global warming to Grade X students?	1) This topic is covered at the end of the second semester, so there is usually not enough time; 2) The material contains many chemical terms; 3) It requires students to do a lot of reading; 4) The teaching methods are still limited to lectures and monotonous discussions; 5) The teacher relies solely on school-provided textbooks, which are limited in number.
What is your opinion on the level of environmental literacy among students at your school?	The students' level of environmental literacy seems to be fairly good.
What is your opinion on students' learning motivation regarding the topic of global warming?	Students' learning motivation seems to be fairly good, depending on the factors that were previously mentioned.
What have you done to provide teaching materials that are relevant to the topic, meet students' needs, and align with technological developments?	Currently, I usually create PowerPoint presentations as learning resources, but even that is rarely done due to the limited number of projectors at the school.

The second step is learner analysis, which involves identifying the characteristics of the target students for the development of the gamification-based e-module, specifically Grade X students. The researcher will tailor the content of the gamification-based e-module according to the characteristics of the students. According to Ardianti & Wanabuliandari (2021), the development of digital learning media should align with the conditions in the field. This step is essential to ensure that the applied innovation can achieve the desired objectives (Hamid et al., 2020). The third step is task analysis, which involves identifying the global warming material that students need to master to meet the minimum competency standards. The learning outcomes at the end of Phase E are that students should have the ability to understand measurement systems, alternative energy, ecosystems, biotechnology, biodiversity,

atomic structure, chemical reactions, basic chemical laws, and climate change, enabling them to be responsive and actively involved in addressing local and global issues. All these efforts aim to achieve the Sustainable Development Goals (SDGs). The fourth step of definition is concept analysis, which is done by identifying the main topics of global warming to be developed, namely: (1) the definition and causes of global warming, (2) the impacts of global warming, and (3) solutions to address global warming. The final step involves setting learning objectives by formulating learning objectives for the topic of global warming, which include identifying the facts of environmental change caused by global warming, identifying human activities that cause environmental change due to global warming, analyzing the impacts of global warming that cause environmental change, and designing solutions to address global warming.

Design stage of the gamification-based e-module on global warming

In the design stage, there are four steps that must be carried out. The first step is to create a criterion-based test, consisting of learning posts integrated with gamification, that aligns with the learning objectives and indicators that students must master, and is adjusted to their cognitive level. In addition, at the end of each sub-chapter, a "Game on! Save our planet!" challenge is included as a competency test, complete with scoring and answer guidelines. The second step is media selection, which is based on the results of the concept analysis, task analysis, and the characteristics of the students as users. The learning resource that will be developed is a gamification-based e-module on the topic of global warming, created using Flip Pdf Corporate. The third step is format selection, which aims to design the e-module. The format of the e-module to be developed is explained in Table 6.

The fourth step of the design phase is the initial design. This initial design consists of the overall design of the learning materials that must be completed before the trial is conducted, including various structured learning activities. In this phase, a storyboard is created to develop the e-module. The material in this e-module is sourced from books, articles, and the internet. The e-module presents images, videos, and various illustrations to help students understand the material and enhance their motivation to learn. When designing the e-module, it is important to use an approach, method, or model to make it more focused and systematic. Furthermore, the relevance of the approach in creating the e-module, the organization of the subject matter content with the learning outcomes in a theme, and the organization of the learning outcomes in that theme are very important (Krissandi & Rusmawan, 2015). The content is contextual or related to real-world environments, meaning students will face environmental issues in everyday life situations and be required to choose the best action to address these issues (Firdaus et al., 2020).

Table 6 Format of the gamification-based e-module

Section of the e-module	Content of the e-module
Beginning	• Cover • Preface • Table of Content • List of Figures • List of Tables • Instructions for Using the E-Module • Features • Learning Objectives
Learning material	• Chapter I Global Warming • Chapter II Impacts of Global Warming • Chapter III Solutions to Address Global Warming
End	• Glossary • References

Development stage of the gamification-based e-module on global warming material

In the development stage, a gamification-based e-module on global warming will be created. This e-module will be designed using Canva and then imported into Flip Pdf Corporate. Canva is an application that can be used to create graphic designs. With Canva, creativity in designing posters, presentations, and other visual content can be developed. This application offers a variety of photos that can be used as illustrations, ready-to-use templates, font styles, and other illustrations to support creativity in design (Sholeh et al., 2020). Flip Pdf Corporate is a software or flash-based flipbook application used to create eBooks or digital modules in a flipbook format (Zinnurain, 2021). Other sources suggest that Flip Pdf Corporate is a flip-based application that provides a book-like display, where the content can include text, images, videos, and other materials for delivering the content (Sumarni &

Dwitiyanti, 2022). The development process of the e-module using Canva and Flip PDF Corporate can be seen in Figure 2.

The e-module integrated with the Flip Pdf Corporate application can be accessed through both laptops and smartphones, such as Android devices, via a browser, making it convenient for students with low storage capacity on their gadgets. This Flip Pdf Corporate application provides a flipping-page effect, mimicking the experience of flipping through a book while reading the e-module. By using Flip PDF Corporate, students are more engaged in learning due to its visually appealing display (Susanti & Sholihah, 2021). The e-module is designed with various navigation buttons that guide students to study independently. This aligns with the statement by Ilmi et al. (2021), who mention that the development of e-modules with clear navigation buttons helps foster student independence. Learning materials utilizing the Flip PDF Corporate application encourage students to study on their own, allowing them to revisit the content until they fully understand what has been learned (Sanz-Angulo et al., 2025). Figure 3 below shows the appearance of the e-module when accessed via a laptop and a smartphone.

Based on previous research, the use of software can enhance the effectiveness of teaching materials, especially when supplemented with elements such as videos, animations, and simulations. Gamification in the e-module will be presented in the form of real games, where students can engage through learning stations that have been prepared in the classroom in groups. Additionally, there will be exercises at the end of each sub-chapter in the form of an online game integrated with the Educaplay website. Practice questions and evaluations are used to help educators assess learning outcomes and improve the competencies and dimensions being measured (Rasmussen et al., 2020). Purwanti et al. (2022) stated that game-based learning, which is commonly used in teaching today, ranges from conventional methods (without using gadgets) to video game-based approaches, using both desktop and mobile devices. Figure 4 presents the design of real games and online games that students can play within the e-module.

After the e-module was developed, the next step is expert appraisal. The validation of the e-module by experts aims to determine its feasibility for use in the classroom learning process. Validation was conducted using an assessment instrument adapted from the components of module content feasibility, graphic design, and language aspects by BSNP, using a 1-4 Likert scale. The content feasibility aspect of the e-module consists of 12 statements, the graphic design feasibility aspect consists of 19 statements, and the language feasibility aspect consists of 12 statements. Validation was carried out by experts, including two university lecturers and one high school science teacher. Figure 5 shows the results of the e-module validation by the three validators across the three aspects.

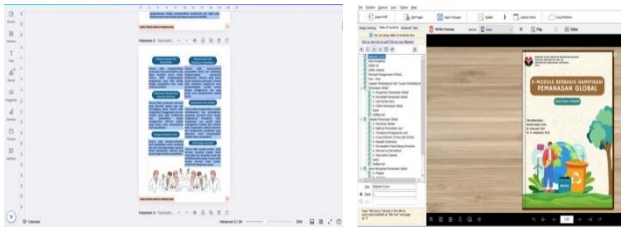

Figure 2
The process of developing the e-module using Canva and Flip Pdf Corporate (in Indonesian)

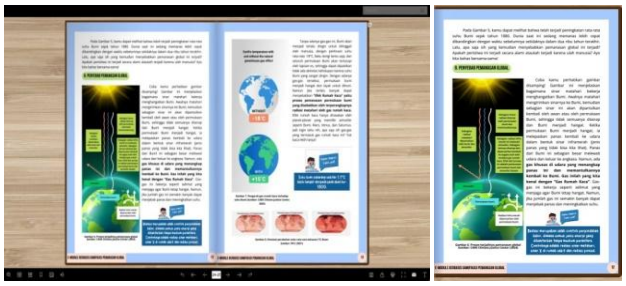

Figure 3
Display of the e-module on a laptop and smartphone (in Indonesian)

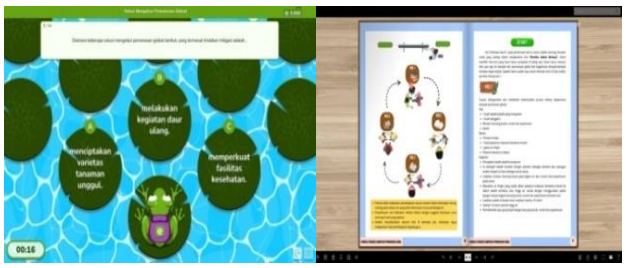

Figure 4
Design view of real games and online games within the e-module (in Indonesian)

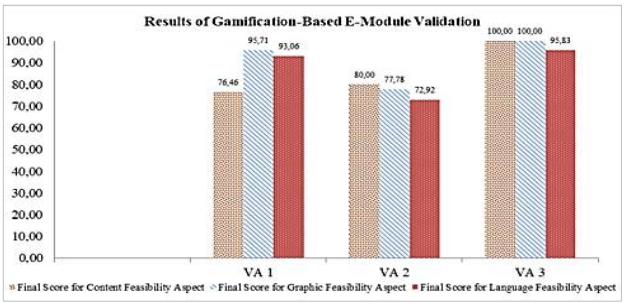

Figure 5
Validation results by expert validators on three aspects

The content feasibility aspect of the e-module consists of four main indicators: alignment with the Merdeka Curriculum, content accuracy, content currency, and encouraging curiosity. Table 7 presents the results of the content feasibility evaluation of the e-module by the three validators.

Table 7 Results of content feasibility evaluation of the gamification-based e-module

Expert validator	Indicators of content feasibility aspect				Final score
	Alignment of content with the Merdeka curriculum	Accuracy of content	Currency of content	Fostering curiosity	
VA 1	83,33	85,00	87,50	50,00	76,46
VA 2	100,00	70,00	75,00	75,00	80,00
VA 3	100,00	100,00	100,00	100,00	100,00
Average	**94,44**	**85,00**	**87,50**	**75,00**	**85,49**

Based on Table 7, the average score for the indicator of content alignment with the Merdeka Curriculum is 94.44, which is categorized as very feasible. This result indicates that the content presented in the e-module covers the material required in the learning outcomes that students need to master, with good breadth and depth. The breadth and depth of the material presented in this gamification-based e-module align with the Merdeka Curriculum for Phase E, making it different from global warming or environmental change materials taught at other educational levels, such as in elementary or junior high school. The material includes the definition and causes of global warming, facts about environmental changes, the impacts of global warming, and solutions to address global warming. Siagian and Yasthophi (2021) stated that teaching materials need to be aligned with basic competencies and learning objectives in order to provide meaningful learning experiences for students.

Next, for the accuracy and currency of content indicator, the average score is 85.00 and 87,50, which is also categorized as very feasible. This means that the concepts and definitions presented do not cause misunderstandings and align with the accepted concepts in global warming material. For example, the definition of global warming refers to the gradual increase in Earth's temperature over time caused by human activities that lead to the accumulation of greenhouse gases in the atmosphere. This definition provides a clear explanation of the relationship between human activities and changes in Earth's temperature. Moreover, this definition is consistent with the scientific understanding widely accepted around the world. Furthermore, the facts and data presented are also relevant to the topic of global warming. The e-module includes solutions in the form of mitigation and adaptation, complete with concrete examples that students can carry out, accompanied by engaging images, and obviously relevant to the material, thereby helping to enhance students' knowledge. The e-module presents material related to real conditions around the students as well as real examples of environmental damage occurring worldwide. According to Ardianti et al. (2017), teaching materials that focus on real environmental situations around students can broaden students' diverse ways of thinking in solving problems. Moreover, the material presented in the e-module is linked to students' daily lives so that they realize environmental issues are close to and relevant in their lives. Learning that emphasizes environmental issues around students can strengthen their understanding (Kinslow et al., 2019). Kartikasari et al. (2018) also stated that learning materials connected to students' daily lives help them in the learning process. For example, in post 3 of the first subchapter, there is a mission to calculate the carbon footprint produced by the students. Material linked to the surrounding environment, complete with examples and images, helps students build understanding independently and absorb the material better (Su'udiah et al., 2016). Information and real examples of environmental damage worldwide also help raise students' awareness of the importance of protecting the environment.

The material in the e-module is presented attractively by combining text, images, illustrations, audio, and video, thereby encouraging students to learn actively. The images and videos in the e-module help depict the ecosystem in the surrounding environment and the impacts that occur if one of the ecosystem components disappears, which can certainly raise awareness and foster environmental care attitudes among students. Furthermore, the images presented facilitate students' understanding of complex and abstract concepts. Saepudin (2018) stated that visualization through images can simplify the understanding of abstract ideas by presenting them in verbal and symbolic forms. Winatha et al. (2018) added that abstract material accompanied by relevant images can help students build knowledge. Selecting appropriate images is very important to prevent misunderstandings (Harsyanda et al., 2024). Additionally, according to Ningsih et al. (2020), the use of e-modules makes the learning process more interactive compared to printed modules that only provide text and images.

Meanwhile, the indicator that encourages curiosity received a score of 75.00, categorized as feasible, indicating that the explanations and examples in the e-module are sufficient to trigger creativity and motivate students to explore the material more deeply. The game elements in the gamification-based e-module, such as points and levels, can stimulate students' curiosity and motivate them to continue the learning process (Srimuliyani, 2023). The overall average score of these four indicators is 85.49, categorized as very feasible, indicating that the e-module is considered suitable for

use in the learning process in terms of content feasibility, which includes alignment with the Merdeka Curriculum, accuracy of the material, material currency, and the teaching material's ability to stimulate curiosity as previously explained. This highly feasible module is suitable for implementation in both classroom and independent learning settings (Zhang et al., 2025).

Table 8 Results of the graphic feasibility test for the gamification-based e-module

Expert validator	Indicator of graphic feasibility aspect			Final score
	Size of the e-module	Cover design of the content	Content design	
VA 1	100,00	91,67	95,45	95,71
VA 2	75,00	83,33	75,00	77,78
VA 3	100,00	100,00	100,00	100,00
Average	**91,67**	**91,67**	**90,15**	**91,16**

The second aspect of the e-module validation is the graphic feasibility. This aspect consists of three indicators: the size of the e-module, the design of the content cover, and the design of the content layout. In Table 8, it can be seen that for the first two aspects, which are the size of the e-module and the design of the cover, they received an average score of 91.67, classified as very feasible. The cover of the gamification-based e-module is well-designed in terms of presentation, size, images used, colors, and layout. The choice of images on the cover is tailored to the topic of global warming. The cover design depicts a young person holding a light bulb with a leaf icon on it, symbolizing an environmentally friendly energy source. The image of the Earth in the background of the cover represents the main topic of this e-module, which relates to the Earth, the planet we live on. Additionally, there is an image of a trash bin with a recycling symbol and the word "recycle," indicating that the waste we discard can still be reused through recycling. The trees, plants, and grass on the cover depict a green, beautiful, and healthy environment. Furthermore, there is an image of a wind turbine as one of the renewable energy sources, which is one of the solutions to tackle global warming. An attractive cover design can increase students' motivation to learn because it can foster their interest in the material presented (Aliyyah et al., 2025). The cover design can be seen in Figure 6.

Meanwhile, the design of the content layout received an average score of 90.15, also classified as very feasible. Regarding the content design aspect, this e-module uses an attractive layout by harmonizing the background, text color, font type, and considering both aesthetic and functional aspects, thus attracting students to learn. Chang et al. (2018) stated that color affects students' memory capacity and cognitive load and can evoke emotions that drive their learning motivation. An interactive e-module created with appealing colors can increase students' interest and encourage their enthusiasm in the learning process. Similar statements were made by Meidina and Marsidi (2019) as well as Ismail and Mawardi (2021), who stated that a colored e-module provides visualization that helps students understand the learning material. According to Syahrul (2019), fonts have specific functional characteristics and meanings, so proper use is essential to ensure the message is conveyed clearly and to minimize misunderstandings. The combination of colors and background used must be designed to be comfortable and easy to read, resulting in an attractive appearance that can increase students' interest in learning (Mumpuni, 2019). Visual aspects can stimulate various abilities in children during the process of achieving their learning goals. Teaching materials that pay attention to color and design aspects can generate students' desire to interact with the learning resources, thereby increasing interest and the quality of learning (Julianto et al., 2021). The overall average score for the graphic feasibility aspect is 91.16, classified as very feasible, indicating that the e-module can be used in the learning process.

Figure 6
Front and back cover of the e-module (in Indonesian)

Table 9 Results of the language feasibility test for the gamification-based e-module

Expert validator	Indicator of language feasibility aspect						Final score
	Clear	Communicative	Dialogical and interactive	Suitability with student development	Compliance with language rules	Use of terms, symbols, or icons	
VA 1	100,00	100,00	83,33	75,00	100,00	100,00	93,06
VA 2	75,00	75,00	62,50	75,00	75,00	75,00	72,92
VA 3	100,00	100,00	87,50	87,50	100,00	100,00	95,83
Average	**91,67**	**91,67**	**77,78**	**79,17**	**91,67**	**91,67**	**87,27**

For the language category, there are six indicators: clarity, communicativeness, dialogical and interactive qualities, suitability with student development, compliance with language rules, and the use of terms, symbols, or icons. This validation is conducted to evaluate the appropriateness of grammar usage, the clarity of the language used, the suitability of the language for the age of the research subjects, sentence efficiency, and the overall readability of the e-module (Utaminingsih & Ellianawati, 2025). Based on Table 9, the overall average score for the language feasibility aspect is 87.27, which is categorized as very feasible. This indicates that the e-module uses clear language, characterized by accurate sentence structure, effective phrasing, and appropriate terminology. Furthermore, the e-module is communicative, enabling readers to understand the conveyed messages and information effectively. It is also capable of motivating students through its attractive design and integrated gamification elements. The e-module encourages critical thinking by presenting various challenges and missions that stimulate students' interest in learning. It is also suitable for students' intellectual and emotional development, as it was designed according to the intellectual abilities of senior high school students. The language used adheres to correct grammar and spelling rules. In addition, the terms used are consistent and relevant to the topic of global warming, and the symbols used in the features and writing are applied consistently. This evidence shows that the gamified e-module developed is appropriate for use in the learning process in terms of language.

From the three validation tests of the gamified e-module, there were several suggestions and feedback provided by the validators, which indicate that some sections of the e-module need improvement. These suggestions are important to ensure the product can be used optimally. Plomp, as cited in Ahdhianto (2016), stated that the quality of the module improves with the number of comments or feedback for improvement. The areas that need improvement include: 1) the gamified e-module should better encourage curiosity and idea development among students, 2) more relevant practice questions should be included, 3) the learning experience of the students before studying this material should be assessed, and 4) examples of the impacts of global warming in Indonesia should be added.

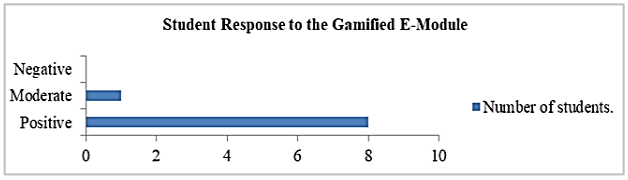

Figure 7
Results of student response questionnaire data analysis

After being validated by experts, the e-module was revised based on the feedback and suggestions provided. The next step after the revision is developmental testing, which aims to obtain responses, reactions, and comments from students regarding the developed gamified e-module. To gather students' responses, a questionnaire was distributed to 9 tenth-grade students. The analysis of the student response questionnaire data is considered effective if ≥ 80% of the students give positive responses to the e-module. Figure 7 presents the summary of student response criteria, where 8 students (89%) gave positive feedback on the e-module. One student (11%) gave a neutral response, and no student gave a negative response. This result indicates that the gamified e-module can be used effectively, as it reached a result of ≥ 80%. A positive student response to the e-module means that the majority of students found the material easy to understand, visually appealing, interactive, and enjoyable. They also found the content relevant to the topic of global warming and useful in daily life. This is in line with the opinions of Aeni and Widodo (2022) as well as Mahendri et al. (2023), who stated that e-modules are interactive and engaging for students.

One student commented: "I am confident that with this e-module, students will be more enthusiastic about reading and will not feel bored when doing assignments, especially when answering questions in the form of games. It is very fun, and students become more meticulous in order to get a higher score than their peers." This comment indicates that students are motivated to win the game, making the learning atmosphere more enjoyable. Another student also commented: "This e-module is interesting, and the explanations make it easier for us to understand." A similar comment was expressed by another student:

"Very interesting and easy to understand." Siman et al. (2022) stated that the development of electronic modules, known as Android-based e-modules, can attract students' interest in reading and studying independently, thereby increasing their motivation to learn. Other studies have also shown that most students find gamified learning enjoyable, engaging, entertaining, and sometimes challenging (John et al., 2021; Li et al., 2018; Manzano-Leon et al., 2022).

D. Conclusion

The gamified e-module on global warming developed in this study is deemed highly feasible for use in the learning process, both from the aspects of content, graphics, and language. Furthermore, the e-module also received positive responses from the students. This result highlights that the integration of digital technology with gamification can have a positive impact on science learning. The development of the e-module in this study was limited to the topic of global warming. Therefore, this research can be further expanded to cover other topics in science and other subjects. Although integrating ICT into education remains a significant challenge today, the concept of learning using gamified e-modules will be an engaging approach for students.

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