



Feasibility Analysis of the Development of STEM-Based Physics E-Book with Self-Regulated Learning on Global Warming Topics

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ABSTRACT

This study aims to analyze the feasibility of a physics e-book based on STEM with self-regulated learning on global warming topics. This research is a design-based research (DBR) using 4D models (define, design, develop, and disseminate). The research sample refers to 3 expert assessments consisting of 2 expert lecturers and 1 senior high school physics teacher. Then the responses of 36 students. The instrument used is an expert validation sheet and legibility tests of the main idea of the e-book on each page. The results of data analysis using Aiken validation show that: 1) the suitability of the material with STEM is 0.83 in the category of valid, 2) the suitability of the e-book with Self-regulated learning (SRL) is 0.78 in the category of valid, and 3) the feasibility of e-book is 0.82 in the category of valid. Meanwhile, the results of the readability test showed a proportion of 99.83% in the good category. So, the development of a physics e-book base on STEM with self-regulated learning on global warming topic is "feasible" to be widely implemented.

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1. INTRODUCTION

To meet the future demands of success in both professional and personal realms, the possession of 21st-century skills is acknowledged as a vital competency standard for students (Novitra et al., 2021). The 21st-century skills are essential competencies for students to face global challenges (Wati & Syafriani, 2023). According to the Partnership for 21st Century Skills, there are four competencies needed in the 21st century, one of these competencies is creative thinking skills. By thinking creatively students can apply various techniques of generating ideas, designing projects, improving projects, and analyzing and evaluating projects to enhance and maximize creative endeavors. However, 21st century learning requires significant innovation, particularly in learning media (Ramli, 2023). Beside of that, digital technology plays a crucial and indispensable role in facing 21st-century education (Yulkifli et al., 2022).

Advancements in science and technology have a significant impact on the challenges and global competition faced by every country (Nazifah & Asrizal, 2022). Besides that, the Covid-19 pandemic has caused a shift from the existing order in education in Indonesia, one of which is changing the curriculum to an independent curriculum. The independent curriculum is a solution that utilizes technology as a response to the demands of the 21st century. This curriculum introduces the concept of "Merdeka Belajar" (Independent Learning), which is specifically designed to aid in the recovery from the learning crisis caused by the COVID-19 pandemic.

This adaptation requires the use of technology, and the need for these competencies serves as one of the foundations in the development of the independent curriculum (Nugraha, 2022). In line with the demands of 21st-century skills and the implementation of the independent learning curriculum at the education unit level, this creates a new challenge for educators to be able to innovate more and continue to update their skills in teaching.

Physics is seen as an abstract scientific discipline that cannot be explained in theory only but must also be accompanied by visualization of existing phenomena, so it is necessary to train in the use of technology in learning which will make it easier for teachers to present visualizations of the phenomena being taught (Amiruddin, 2022).

The use of technology is felt to be able to overcome difficulties as well as a tool in learning physics (Gunawan & Amaludin, 2021). Teachers can utilize technology to create interactive learning materials. Learning materials serve as a medium to transmit messages from sources to recipients, facilitating the learning process. With the advancements in science, particularly in the field of physics, learning materials can be innovated. One example of such learning material is an electronic book (Novita, 2023). The intended electronics are in the form of computers or laptops that can be used to download applications to support learning in class (Lestari et al., 2018).

One of the approaches that can develop 21st-century skills in STEM. STEM education focuses on developing graduates who possess STEM literacy and the necessary skills to excel in the technologically oriented future workforce (Hamad et al., 2022). STEM-based learning is considered appropriate because the use of the STEM approach in learning can improve logical thinking skills, and critical and creative thinking skills, and improve students' understanding of concepts (Lock et al., 2019).

The application of STEM-based learning was effective in training the 21st-century skills of Gen-Z students in science learning (Ichsan et al., 2023). In line with that, STEM can increase effectiveness, create meaningful learning, and influence students' attitudes toward pursuing future careers (Samsudin et al., 2020). The enhancement of creative thinking abilities and

students' capacity for independent learning is not solely shaped by external elements but is also influenced by their internal capabilities, commonly known as self-regulation. Self-regulated learning (SRL) facilitates the development of various skills in students, such as cognitive abilities, creative thinking skills, and problem-solving skills. When self-regulated learning manifests in students, it establishes a learning pattern that consistently recurs until they ultimately attain self-regulation (Zimmerman, 1989).

SRL is important in learning physics with abstract material. Thus, learning becomes fun and meaningful. By integrating SRL into the learning process, students have the ability to actively set learning goals, plan their learning, monitor their learning progress, and adjust their study plans (Heryani *et al.*, 2023). So far, however, there has been little discussion about the development of stem-based e-books and self-regulated learning in science lessons, especially physics.

This research focuses on the development of STEM-based physics e-books with self-regulated learning on global warming topics. The developed STEM-based e-book can be accessed by students via an html link using a smartphone and adapted to the independent learning curriculum. Thus, it contains learning outcomes, Pancasila student profiles (P3), and is equipped with a glossary. The e-book is also equipped with an SRL agent that helps students study the material in the e-module independently. Each sub-material in the e-book will display STEM aspects such as material concepts (science), technology in the form of measurement tools in the material (technology), engineering activities (engineering), and curves or tables (mathematics).

2. THEORY

2.1. E-Book

E-books are distinguished by their utilization of color images, animations, simulations, and videos (Novita, 2023). Textbooks are included in teaching materials developed to support learning for students in the classroom. Various types of physics e-books have been developed for learning purposes, such as web-based and android-based e-books. These e-books offer different formats and platforms to enhance physics learning activities (Ndoa, 2022). Meanwhile, according to Lestari (2018), the characteristics that must be considered in a teaching material or textbook are being able to make students teach themselves (Self-instruction), containing all subject matter in one unit of competency that can be learned in the module as a whole (Self-contained), the module does not depend on other modules or media (Standalone), the module is adapted to the development of science and technology and is flexible if used in the learning process (Adaptive), can help and facilitate users in using the module (User friendly).

In this study, the e-book was created using the "Book Creator" website. Book Creator is a website used to create E-books, E-modules, and other types of books electronically in the form of flip books with output in the form of HTML or EPUB format files. Besides being easy to use, book creator is also said to be attractive, because the tools available are not only in the form of text and images like ordinary reading books but can also insert audio and video records. Book Creator is also connected to several applications such as Canva to make it easier to design modules, and google drive to access questions that will be included in the e-book online.

2.2. STEM (Science, Technology, Engineering, and Mathematics) Approach

The integration of STEM has been defined as the merging of science, technology, engineering, and mathematics to solve real-world challenges by utilizing students'

experiences to enhance skills that are relevant to the 21st century (Sulaeman et al., 2022). STEM integration is also defined as a space where STEM problems originate from the real world, connected through concepts and skills, representing multiple disciplines, providing structure for integration, and allowing room for participant collaboration (Kilty & Burrows, 2022). The STEM disciplines consist of four main fields, namely:

- (i) Science: This field encompasses the study of nature and natural phenomena, including physics, chemistry, biology, astronomy, and environmental science.
- (ii) Technology: This field is related to the development and application of tools, machines, devices, and systems used to solve problems and meet human needs. Examples of fields within technology include computer engineering, electrical engineering, mechanical engineering, and civil engineering.
- (iii) Engineering: This field involves the design, construction, and utilization of structures, machines, systems, and processes to solve problems and meet human needs. Examples of fields within engineering include civil engineering, chemical engineering, electrical engineering, and mechanical engineering.
- (iv) Mathematics: This field involves the study of patterns, structures, and quantitative relationships. Mathematics is used to model and solve problems in various fields, including science, technology, and engineering. Examples of fields within mathematics include algebra, geometry, calculus, and statistics.

2.3. Self-Regulated Learning (SRL)

Self-regulated learning is an ability where a person can activate and encourage thoughts (cognition), feelings (affection), and actions (action) that have been planned systematically and repeatedly oriented to achieve a goal in learning. Self-regulated learning takes place when students systematically provide knowledge, repeat information to be remembered and develop and maintain positive beliefs about learning ability (self-efficacy) and can anticipate learning outcomes. In addition, when self-regulated learning emerges, a learning pattern will be formed that will continue to be repeated in students. There are three phases of the process that students must go through to finally achieve self-regulation in learning, namely the forethought phase, performance phase, and Self-reflection phase (Zimmerman, 1989).

2.4. STEM-based Physics E-Book with Self-Regulated Learning (SRL-Agent)

The developed STEM-based e-book will be equipped with an SRL agent that helps students learn the material in the e-module independently. Each sub-material in the e-book will display what STEM aspects are loaded such as material concepts (science), technology in the form of measuring instruments in the material (technology), engineering activities (engineering), and graphs or tables (mathematics). The SRL agent in the e-book will be described in three phases of the cycle as previously described.

The phases consist of the planning phase where this phase presents a choice of strategies for solving tasks by adding motivational words. Next is the implementation or performance phase which provides information again about the theory needed to complete the task. And the last phase is the self-reflection phase which provides direction. Thus, the strategy used is correct and determines the extent to which students understand the task given. This cycle will continue to rotate, if students still do not understand what is learned in the evaluated phase then students will be directed back to the first phase. With the SRL agent in the e-book, it is expected to foster students' learning independence.

3. METHODS

This research is a design-based research (DBR) using a 4D model, namely: define, design, develop, and disseminate. However, this research is limited only to the development phase. The phase in the 4D model is shown in **Figure 1**.



Figure 1. The DBR with a 4D model that is modified into 3D.

This research was conducted at senior high school (i.e. SMAN 2 Pangkalan Kerinci, Riau) on global warming topics in class X even semester of the 2022/2023 academic year. The research sample refers to 3 expert judgments consisting of 2 expert lecturers and 1 senior high school physics teacher. Then the responses of 36 students. Data collection techniques are carried out through non-test instruments, including an expert validation sheet and legibility tests of the main idea of the e-book on each page. The results of data analysis using Aiken validation are shown in Equations (1) and (2):

$$V = \frac{\sum s}{|n(c-1)|} \quad (1)$$

$$S = r - l_0 \quad (2)$$

where V is the Aiken validation value; r is the number given by the validator; l_0 is the lowest validity rating score; c is the highest validity rating score; and n is the number of panelists.

From the results obtained, the data which was originally in the form of quantitative was changed to descriptive qualitative. The e-book validity quality can be determined by the validity category (see **Table 1**).

Tabel 1. Validity category.

intervals	Category
$\geq 0.61 - 1,00$	Valid
< 0.61	Invalid

The readability test of this module is carried out using questions according to which consist of four parts, namely: 1) the main ideas of the discourse, 2) details of supporting discourse that support the main idea, 3) words that are not understood and 4) sentences that are difficult to understand. The data obtained is processed using the Guttman scale. Besides being able to make a multiple choice Guttman scale, it can also be made in the form of a checklist, where answers can be made with the highest score of one and the lowest score of zero. This instrument if students understand, they will be given 1 point, while students who do not understand are given 0 points which will then be analyzed using the percentage value (P) as follows:

$$\text{percentage value } (p) = \frac{\text{total score given}}{\text{overall score}} \times 100\% \quad (3)$$

After obtaining the results, then interpreting the readability of the e-book with a classification based on the following criteria described in **Table 2**.

Tabel 2. E-book readability interpretation criteria.

Intervals	Category
$77.77 < x \leq 100$	High
$55.54 < x \leq 77.77$	Medium
$33.31 < x \leq 55.52$	Low
$x < 33.31$	Very low

4. RESULTS AND DISCUSSION

4.1. Define

4.1.1. Curriculum analysis

The curriculum used in this school is the Independent Curriculum Class 1. So grades XI and XII still use the 2013 curriculum.

4.1.2. Student analysis

After conducting a preliminary study it was found that learning activities in schools were still conventional and still teacher-centered. This resulted in students considering physics subjects to be very difficult and boring.

4.1.3. Analysis of learning materials

The material that will be implemented in class is global warming topics.

4.1.4. Analysis of learning objects

Analysis of learning objectives is carried out by adjusting learning outcomes, tasks, and existing concepts and then connecting them with the behavior of the subjects to be achieved, namely increasing creative thinking skills and student learning independence.

4.2. Design

4.2.1. Preparation of validation instruments

The STEM-based physics E-book validation instrument with Self Regulated Learning in the form of expert lecturer and physics teacher validation sheets in the form of a checklist in the column containing the level of suitability scale. The validation instrument consists of 3 parts, namely: 1) the suitability of the material with STEM, 2) the suitability of the e-book with SRL, and 3) the feasibility of the e-book. The readability test of this module is carried out using questions which consist of four parts, namely: 1) the main ideas of the discourse, 2) details of supporting discourse that support the main idea, 3) words that are not understood and 4) sentences that are difficult to understand. The data obtained is processed using the Guttman scale.

4.2.2. E-book design

E-books were created using the "Book Creator" website. Book Creator is a website that is used to create e-books, e-modules, and other types of books electronically in the form of flip books with output in the form of HTML or files in EPUB format. Besides being easy to use, the book creator is also said to be attractive, because the tools available are not only in the form of text and pictures like ordinary reading books but can also insert audio and video records. The book creator is also connected to several applications such as Canva to make it easier to design modules, and Google Drive to access questions that will be included in the e-book online. The ebook design can be seen in **Figure 2**.

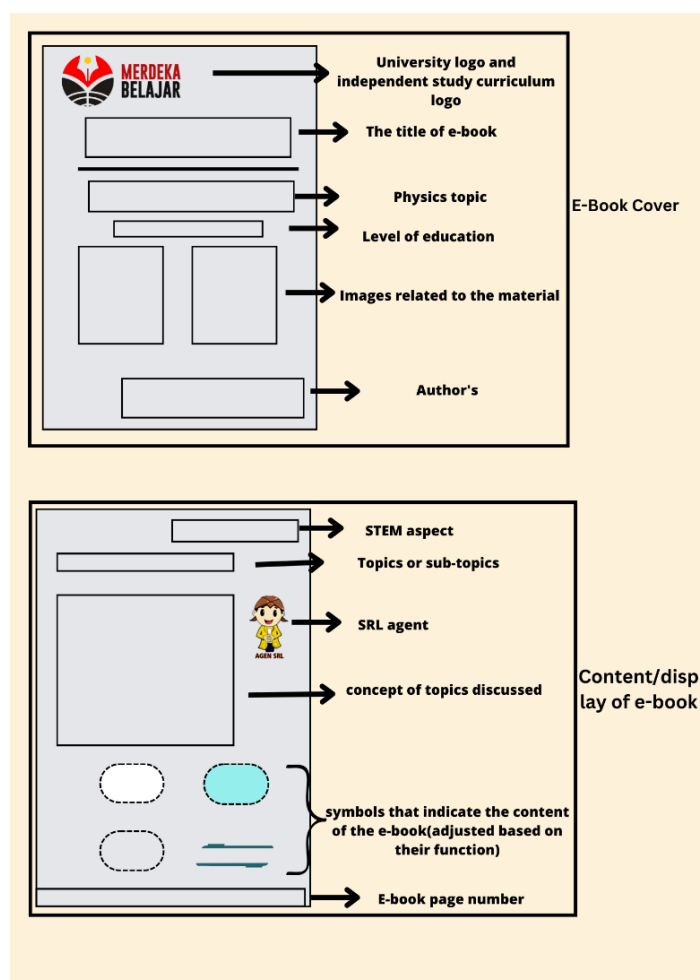


Figure 2. E-book design display.

4.3. Develop

4.3.1. E-book validaon

The validity test aims to determine the level of product validity as measured based on the validator's assessment consisting of 2 lecturers from the Masters of Physics Education Universitas Pendidikan Indonesia and 1 physics teacher at a senior high school in Riau. The results of the validators' assessment are shown in **Table 3**.

Table 3. Table analysis of e-book validation results by the expert.

Component	Validation	Category
The suitability of the material with STEM	0.83	Valid
The suitability of the e-book with SRL	0.78	Valid
The feasibility of e-book	0.82	Valid

Based on the results in **Table 3**, it can be seen that the results of the validation test on the aspect suitability of the material with STEM are 0.83 in the valid category, The suitability of the e-book with SRL is 0.78 in the valid category, and The feasibility of e-book is in 0.82 in the valid category. This is because the developed e-book fulfills the assessment aspects of the validation instrument.

4.3.2. Readability test of e-book

The readability test aims to find out whether STEM-based e-books with self-regulated learning already use language that users can understand or not (see **Table 4**). Based on the results in **Table 4**, it can be seen that the results of the readability test conducted by 36 class x students were in the high criteria, namely 99,83%. While the percentage of students who do not understand is 0.17% at low criteria. The percentage of students who do not understand is on page 9 with the reason that the writing on the graph of the increase in CO₂ emissions is too small. Variations in students' comprehension of reading modules can stem from the individual abilities possessed by each student.

Table 4. Table results of the readability test.

Sample	Score max	Percentage		Criteria
		understand	Don't understand	
36	33	99.83	0.17	High

5. CONCLUSION

Based on the results of the discussion, it can be concluded that the STEM-based physics e-book with self-regulated learning on global warming topics developed is feasible because Obtaining valid criteria in each validation category, including (1) The aspect suitability of the material with STEM is 0.83 in the valid category, (2) The suitability of the e-book with SRL is in 0.78 in the valid category, and (3) The feasibility of e-book is in 0.82 in the valid category. Meanwhile, the results of the readability test showed a proportion of 99.83% in the good category. Thus, the development of a physics e-book base on STEM with self-regulated learning on global warming topic is "feasible" to be widely implemented.

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7. AUTHORS' NOTE

The authors declare that there is no conflict of interest regarding the publication of this article. The authors confirmed that the paper was free of plagiarism.

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