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Development of STEM-Based Physics E-Module with Self-Regulated Learning to Train Students' Creative Thinking Skills

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Abstract

Twenty-first century skills are recognized as a competency standard that students need to possess to support the demands of success both in work and in life in the future, especially in learning. In line with this, learning that can accommodate 21st-century skills is learning that has a balance between the scientific approach and the use of technology. One of the efforts that can be made is to develop teaching materials in the form of electronic modules that integrate Science, Technology, Engineering, and Mathematics (STEM) to train creative thinking skills that are also adjusted to the applicable school curriculum. However, most of the teaching materials, especially the modules that are used in general, are only printed modules. Based on these problems, we need electronic modules (e-modules) that direct students to have 21st-century skills and the dimensions that exist in the independent learning curriculum. This study aims to develop an e-module based on STEM and self-regulated learning about global warming topics to train students' creative thinking skills. This type of research involves adapting a 4-D development model. Which consist of defining, designing, developing, and disseminating. The data were gathered through questionnaires and tests. The questionnaire instrument consists of an expert validation questionnaire of three experts. Meanwhile, the test instrument consisted of a pre-test and a post-test, which were tested on 32 students in class X majoring in science. The N-gain score for creative thinking skills is 0.60 in the medium category. Based on the results of this study, the development of a STEM-based physics e-module with self-regulated learning on the global warming topic can train students' creative thinking skills.

Keywords: e-module, STEM, self-regulated learning, creative thinking skills

INTRODUCTION

Twenty first (21st) century skills are recognized as a competency standard that students need to have to support the demands of success in both work and life in the future (Novitra et al. 2021). All elements of both educators and educational targets must prepare themselves to face 21st-century education. The competencies needed in the 21st century or known as The 4Cs include critical thinking, collaboration communication, and creativity (Partnership for 21st Century Skills 2015). In line with the demands of the 21st century, the curriculum in education units also determines the future of students because the curriculum is responsible for influencing the pace and teaching methods used by teachers to meet the needs of students (Kemendikbudristek 2022a). The curriculum currently implemented in education units is the independent learning curriculum. The Independent Learning Curriculum is a restructuring of Indonesia's national education system (Rahayu et al. 2021). The independent learning curriculum

emphasizes the development of 21st-century skills, this is because the dimensions in the independent learning curriculum include dimensions of faith, fear of God Almighty, and noble character, dimensions of global diversity, dimensions of cooperation, independent dimensions, dimensions of critical reasoning, and creative dimensions which are expected to emerge as the profile of Pancasila learners for students (Kemendikbudristek 2022b).

In utilizing students' knowledge for problem-solving and decision-making in various areas of life, higher-order thinking skills, especially creative thinking skills, are very important because they have a significant role in the decision-making process when faced with various choices (Sumarni and Kadarwati 2020). According to PISA (OECD 2019), creative thinking is defined as the ability to actively engage in generating, evaluating, and improving ideas to produce original and effective solutions, advances in knowledge, and expressions of imagination that have an impact. This definition is in line with the view presented by the Creative Thinking Strategic Advisory Expert Group (OECD 2017), which states that in all contexts, students need to learn how to engage productively in the practice of generating ideas, reflecting on ideas by appreciating their relevance and innovation, and iterating on them until a satisfactory idea emerges and the desired outcome is achieved.

A learning approach that can train student's creative thinking skills is STEM. The use of a STEM-based learning approach that is integrated into learning activities is seen as an appropriate method because its use can improve logical thinking skills, critical and creative thinking abilities, and understanding of students' concepts. This is achieved through the use of learning materials and Learner Worksheets (LKPD) oriented to the STEM approach (Lock et al. 2019). Science and engineering activities integrated with the STEM approach in learning have an impact on students' confidence in physics performance and competence so it is important to involve science and engineering activities outside the classroom that not only aim to increase students' performance confidence and competence but also student interest, especially for those who were previously less interested, so that they can become more interested and like physics lessons (Winarti et al. 2022). STEM education can support students who initially do not show a direct interest in STEM disciplines, helping them develop an interest in STEM and consequently fostering the development of various skills such as computational thinking, creativity and motivation, collaboration and teamwork, problem-solving, and other higher-order thinking skills (Darmawansah et al. 2023). The application of STEM-based learning can be presented through interactive media (Kurniawan et al. 2023). The development of student's creative thinking skills is not only influenced by external factors but also influenced by the student's own abilities (internal), which is often referred to as self-regulated which allows students to have the ability to organize and direct themselves, as well as adjust and control themselves, especially when facing difficult tasks (Sucipto et al. 2022). Self-Regulated Learning (SRL) has the potential to develop learners' skills, including cognitive skills, creative thinking skills, and problem-solving skills. When self-regulated learning occurs, certain learning patterns will form and repeat in students until they reach a better level of self-regulation (Zimmerman 1989).

Improving students' learning experience can be obtained through a variety of ways, one of which is through the use of multimedia integrated into teaching materials for classroom learning (Astra et al. 2023). Following the different learning styles of students, some students can understand the lesson simply by providing text material only, some students are more responsive to learning that uses visuals, while others are likely to prefer learning that is also accompanied by auditory. Teaching materials used in schools mostly only contain text and images, so the use of technology in learning is needed to make it easier for teachers to display visualizations of the phenomena being taught (Bin 2022). The use of technology is considered a tool that can overcome difficulties in learning physics (Gunawan and Amaludin 2021). In line with this, the application of ICT in learning can make learning more meaningful for students (Aprianti et al. 2023). The development of teaching materials in the form of flipbooks is considered a very helpful medium for subjects that are abstract and require visualization (Febrian et al. 2023). The advantage of electronic modules is their ability to present audio, visual, and audio-visual content that can be integrated into a single product (Lestari and Apsari 2022). Based on the problem description above, the researcher developed a STEM-based Physics e-module with self-regulated learning to train students' creative thinking skills on global warming topics.

METHODS

In this study, the Research and Development (R&D) method was used. R&D is a research method that aims to produce certain products and test their effectiveness. The product tested for effectiveness in this study is a STEM-based physics e-module with self-regulated learning (SRL) as a learning approach. According to (Sugiyono 2016), R&D is a method used to develop products and test their effectiveness. The research model used follows the 4D model. This model was first developed by Thiagarajan (1976) consists of four relatively simple stages, namely define, design, develop, and disseminate. The phase in the 4D model are shown in FIGURE 1.

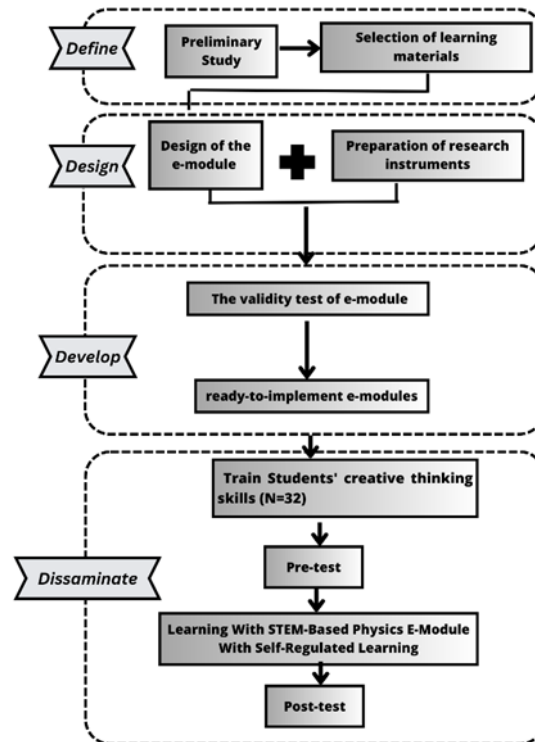


FIGURE 1. The R&D Research Design uses a 4D model

In the define stage, researchers conducted a preliminary study includes curriculum analysis, student analysis, and material analysis that will be utilized. The next stage is design which aims to design of the e-module and the preparation of learning tools in the form of validation sheets and criterion reference tests. The criterion reference test is the stage where researchers compile instruments used to assess the feasibility of the developed e-module (validation instrument). Then compile an instrument to assess creative thinking skills. The next stage is develop which is a follow-up to the e-module design to be validated by validators (expert lecturers and physics teachers). The purpose of this stage is to produce learning e-modules that are good and feasible to use. The final stage is dissemination, where researchers implement the e-module in schools for testing with students and document the research findings in scientific journals. The effectiveness of the e-module was evaluated on the topic of global warming, to practise students' creative thinking skills through the administration of pre-test and post-test. The results obtained from the pre-test and post-test were used to determine the level of student's creative thinking skills based on the calculated N-Gain score. The comparison between the pre-test and post-test results was calculated using the N-Gain score. The N-Gain equation is as follows:

$$\langle g \rangle = \frac{(S_f) - (S_i)}{(S_{\max}) - (S_i)} \tag{1}$$

- $\langle g \rangle$: *N-gain* score
- (S_f) : Post-test average
- (S_i) : Pre-test average
- (S_{max}) : Maximum score

The results of the N-Gain average calculation were then interpreted using the criteria listed in TABLE 1.

TABLE 1. Division of Gain Score

$\langle g \rangle$	Category
$\langle g \rangle \geq 0,7$	High-g
$0,3 \leq \langle g \rangle < 0,7$	Medium-g
$\langle g \rangle < 0,3$	Low-g

(Hake 1999)

RESULTS AND DISCUSSION

Define

After conducting observations, information was obtained that the intended school implemented an independent learning curriculum. Based on teacher interview result, physics learning activities in the classroom are still conventional and teacher-centered. Physics teachers have not developed their own teaching modules and learning activities and have not directed students to practice 21st-century skills, especially creative thinking skills. The material to be applied in the classroom is the topic of global warming.

Design

The design stage begins with developing e-module layout, and research instruments in the form of an e-module validation sheet in the form of a checklist in a column containing a scale of suitability levels. The validation instrument consists of compatibility of the e-module with STEM, compatibility of the e-module with SRL (Self-Regulated Learning), and the suitability of the language and presentation of the e-module. Next is the e-module readability test instrument. At the same time, researchers compiled an instrument for creative thinking skills that refers to PISA 2021 in the form of an extended written-response with an essay type on global warming topics.

The next design is the creation of an e-module designed using the Canva application, then the e-module is converted into a flip book form using the "Book Creator" website. On the book creator's website, components such as videos and questions in the form of Google forms can be inputted. Each sub-material in the e-module will display what STEM aspects are contained, for example, the concept of global warming topics (science), technology in the form of measuring instruments in the material (technology), engineering activities (engineering), and graphs or tables (mathematics). The activities in the e-module also direct students to think creatively. There is an SRL agent that will be depicted in a character as in FIGURE 2. The SRL agent will provide sentences that help students understand the e-module. The SRL agent in the e-module will be depicted in three phases, namely the forethoughts phase, the performance phase, and the self-reflective phase which will continue to rotate. The developed e-module is equipped with an e-module design that can be seen in FIGURE 1.

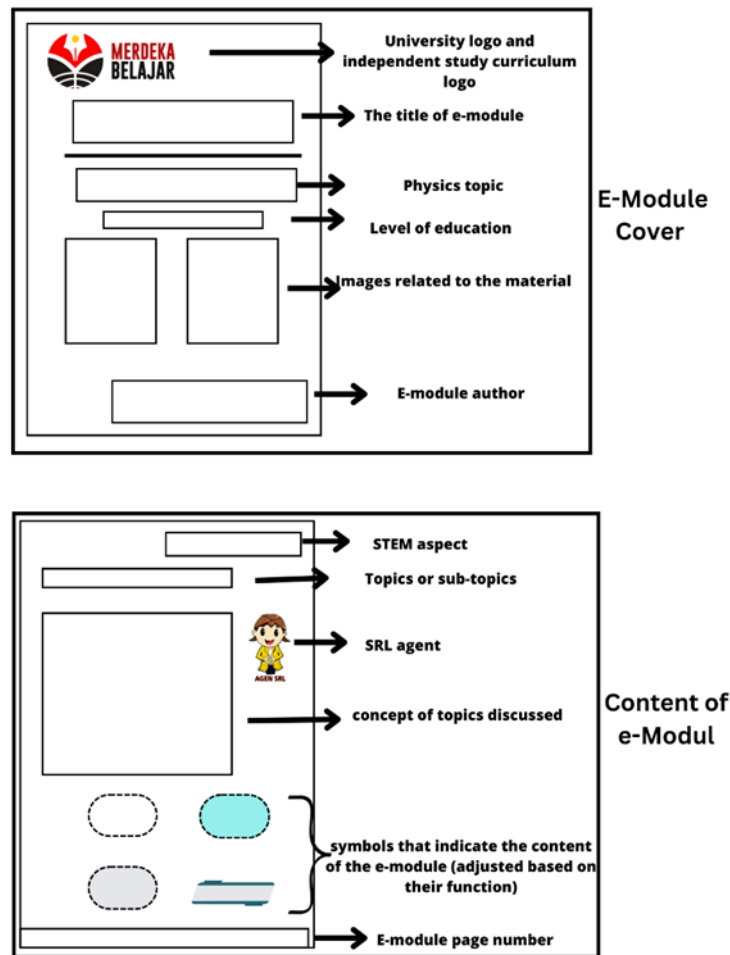


FIGURE 2. Layout of e-module

Develop

During the develop stage, researchers work on improving the e-module that has been produced through e-module validation. In the validation stage, the developed e-module is tested for its suitability by three experts. The experts' assessment is based on indicators that include the compatibility of the e-module with STEM, the compatibility of the e-module with SRL (Self-Regulated Learning), as well as the suitability of the language and presentation of the e-module. The results of the e-module's suitability validation can be seen in the FIGURE 3.

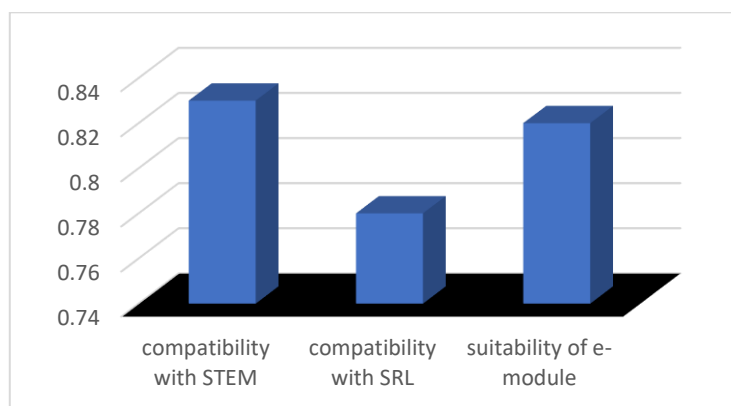


FIGURE 3. validation of e-module

FIGURE 3 shows that the average value obtained is $\geq 0.61 - 1.00$ and is categorized as valid according to Azwar (2015).

Disseminate

Based on the results of the study, data on students' creative thinking skills were obtained, including pre-test and post-test scores. The results indicated an improvement after implementing physics e-modules based on STEM with self-regulated learning. The test on creative thinking skills referred to the PISA 2021 indicators, namely: 1) Generating diverse ideas in the written domain and 2) Evaluating and improving ideas in the visual domain (OECD 2019). The students' responses were assessed using a rubric that aligned with Torrance's aspects of creative thinking, including fluency, flexibility, originality, and elaboration (Torrance 1969). The graphs of pre-test and post-test results for each indicator of creative thinking skills are shown in FIGURE 4.

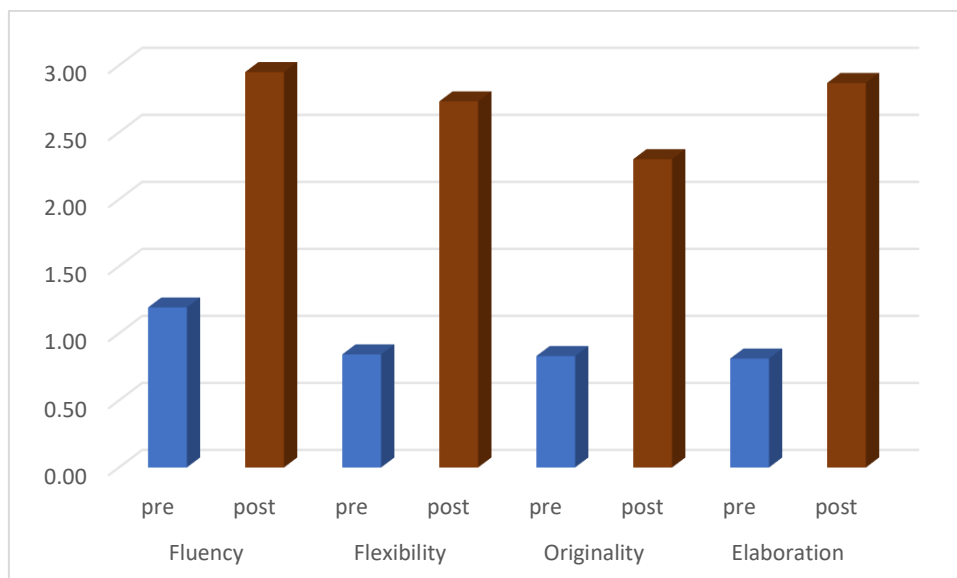


FIGURE 4. The graphs of pre-test and post-test results for each indicator of creative thinking skills

According to the FIGURE 3, for the fluency aspect, students obtained an average pre-test score of 1.19 and an average post-test score of 2.95. There was an increase in scores when students had not yet used the implemented e-module and when the e-module had been implemented. This is because students' ability to generate diverse ideas and suggestions regarding a problem or phenomenon has improved. In the second aspect, which is flexibility, students obtained an average pre-test score of 0.84 and an average post-test score of 2.73. There was an increase in scores when students had not yet used the implemented e-module and when the e-module had been implemented. This is because students' ability to generate diverse ideas with a broader scope regarding a problem or phenomenon has improved. The third aspect, which is originality, experienced an increase in the pre-test score from 0.83 to 2.30 in the post-test score. Students who previously suggested answers that were almost the same as their peers became more creative by proposing multiple unique and different answers to the given problem.

The last aspect is elaboration, and in this aspect, there was an increase in both pre-test and post-test scores of the students. The average pre-test score was 0.81, while the average post-test score was 2.87. This is because students' ability to elaborate and clarify all parts of the generated ideas has improved compared to before using the e-module.

The comparison between the pre-test and post-test results was calculated using the N-Gain score. The N-Gain score obtained from 32 students has an average of 0.60. The N-Gain scores for each aspect of creative thinking can be seen in FIGURE 5.

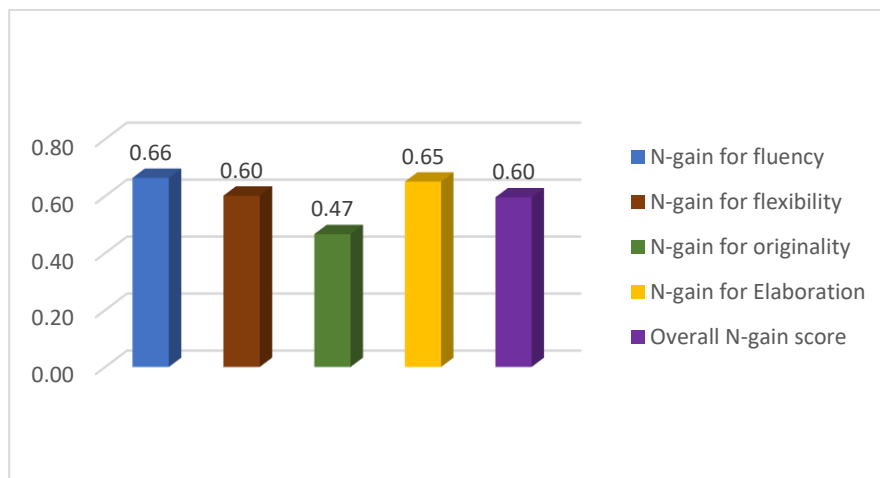


FIGURE 5. The results of the N-Gain scores for each aspect of creative thinking skills

Based on FIGURE 4, it can be observed that the N-Gain scores have different results of each aspect of creative thinking. The aspect with the highest N-Gain score is fluency, which is 0.66, while the lowest N-Gain score is found in the originality aspect, which is 0.47. The fluency aspect can be attributed to the student's ability to generate multiple ideas and suggestions for a problem or phenomenon. The given problems are related to everyday life events and can be derived from their daily life experiences in the surrounding environment. Therefore, the researcher can conclude that these students have extensive knowledge, enabling them to provide ideas smoothly. On the other hand, the lowest score in the originality aspect, where students are expected to provide unique and different answers that are uncommon among other students. This becomes a challenge for students because some of them have answers that are almost the same as those of other students. N-gain scores obtained from 32 students, there are 1 student who get N-Gain scores in the low category, 22 students who get N-Gain scores in the medium category, and 9 students who get N-Gain scores in the high category. The overall average N-gain score of 0.60 is in the medium category.

Relevant research to this study is conducted by (Dewi et al. 2019), with similar findings where the highest N-Gain score is found in the fluency aspect, and the lowest N-Gain score is found in the originality aspect. Another relevant study conducted by (Parno et al. 2019) states that STEM cycle-based learning is capable of improving students' creative thinking skills from a level of almost non-creative to creative.

CONCLUSION

Based on the results and discussion, it can be concluded that the STEM-based physics e-module with self-regulated learning on global warming topics developed can train students' creative thinking skills by obtained an N-Gain value of 0.60 with a medium category. Physics e-modules based on STEM and self-regulated learning on global warming material can be used in the physics learning process of class X Senior High School.

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