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Development of STEM-Based E-Learning on Renewable Energy Topic to Improve the Students Creative Thinking Skills

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Abstract: Education has a major role in facing the challenges of the 21st-century through Education for Sustainable Development (ESD). The Merdeka Curriculum came as an idea to change the quality of education in Indonesia. However, the availability of learning resources is still very low, not yet phenomenon-based, multidisciplinary, and not oriented toward improving 21st-century skills. This has an impact on the low creative thinking skills of students. These skills are a necessity and can only be produced through phenomenon-based learning, studied in multidisciplinary ways, such as STEM learning. It is necessary to develop learning resources such as STEM-based e-learning. This study aims to develop STEM-based learning that is feasible and acceptable using the Alessi and Trolip development model. The research subjects were students of class X of SMAN 2 Palembang. The results showed that the alpha test of the product was suitable for use with an acceptable percentage of 100%. The beta test results of the product can be accepted by 100% of students. This study concludes that STEM-based renewable energy e-learning to improve the creative thinking skills of high school students has been feasible and acceptable to students. Furthermore, it can be used for the effectiveness test stage.

Keywords: Creative Thinking; E-Learning; ESD; *Merdeka* Curriculum; STEM

Introduction

Education for Sustainable Development (ESD) has a major role in facing the challenges of globalization in the 21st century (Fekih Zguir et al., 2021). The integration of ESD in education in Indonesia is reflected through the revitalization of the curriculum into a *Merdeka* Curriculum. The *Merdeka* Curriculum was developed as a more flexible curriculum while focusing on essential materials and developing students' skills, character, and competencies (Barlian et al., 2022). Through the implementation of the *Merdeka* Curriculum, the focus of students' skill development is no longer only on low-level thinking skills, but on high-level thinking skills (Hasanah et al., 2021; Hasibuan et al., 2022). However, until now, the high-level thinking skills of students in Indonesia are still far from good, one of which is creative thinking skills (Syukri et al., 2021).

This is evidenced by the results of previous research which shows that the percentage of students' creative thinking skills, especially in physics learning, is still in the low category (Muflikhun & Setyarsih, 2022; Nazhifah et al., 2023; Rahmawati et al., 2022; Trisnayanti et al., 2020; Wulandari et al., 2021). Supported by initial observations and interviews of physics teachers that have been conducted at SMAN 2 Palembang, showed similar results. It can be seen that when given tasks, students tend to be lazy to work on questions that they think are difficult and slightly different from the example of questions given by the teacher because students are not accustomed to being trained and directed to think creatively in solving problems.

The findings are in line with the opinion of Arini (2017) that the teacher provides practice questions and repetitions that are similar to the examples of questions that have been discussed so that the characters of

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students who appear are only preparing themselves to memorize and learn what has been explained by the teacher. Then the results of observations of 4 physics materials in phase E of the *Merdeka* Curriculum as many as 47.6% of students stated that it was difficult to master the subject matter of renewable energy. Whereas these skills can provide great opportunities for students to explore their knowledge in physics learning (Athifah & Syafriani, 2019; Sumarni & Kadarwati, 2020) and see the relationship between the knowledge they acquire and real-life phenomena (Idin, 2019; Setyarini et al., 2020; Wulandari et al., 2021).

Based on these problems, it is suspected that the learning system is not yet fully effective in building students' ideas (Suherman et al., 2021), and some teachers still do not fully understand the implementation of learning and assessment in the *Merdeka* Curriculum (Susilowati, 2022), in addition to the lack of *Merdeka* Curriculum learning resources that support the improvement of student's creative thinking skills (Maulinda, 2022). These skills will develop well if the learning is carried out deliberately to encourage the thinking potential of students and manage it in a planned manner with good learning planning. Therefore, learning resources are needed that support the implementation of a planned and systematic learning process. The solution to overcome this problem is to innovate in the learning process such as developing STEM-based e-learning (Sirajudin et al., 2021; Wiyono et al., 2022).

Integrating STEM approaches in the physics learning process will provide solutions to existing problems. This approach involves learning four STEM fields (science, technology, engineering, and mathematics) based on the phenomena surrounding students to develop creative thinking skills (Jawad et al., 2021; Sumarni et al., 2022; Sumarni & Kadarwati, 2020). STEM learning is an educational trend in the industrial era 4.0 and is internationally recognized to be able to improve the skills needed by 21st-century society (Aykan & Yıldırım, 2022; Turner et al., 2022). In addition, STEM approaches enable learners to solve problems better, they are also able to become innovators, inventors, independent workers, logical thinkers, and technology literates (Sumarni & Kadarwati, 2020).

The application of STEM learning is considered effective to be applied as integrative thematic learning because it is carried out through projects that are integrated with various disciplines in everyday life (Pangesti & Triyanta, 2022; Simeon et al., 2022). This is also in line with the implementation of the *Merdeka* Curriculum which emphasizes more on project-based learning (Triwulandari et al., 2022). The results of research in Indonesia show that STEM learning displays good results and students who use the learning have better 21st-century skills (Adhelacahya et al., 2023; Nazifah & Asrizal, 2022; Saefullah et al., 2021; Shukri et al., 2020; Surya et al., 2018). Thus, STEM learning can be applied to the *Merdeka* Curriculum and supported by adding aspects of creative thinking and ESD.

The implementation of continuous learning in the 21st-century has benefited a lot from the development of Internet technology (Febrian et al., 2021). One of the applications of the internet in the implementation of learning is using e-learning. This technology is widely used with the aim that education increasingly exists and can adapt to the conditions of the times so that education packaging becomes more attractive and transforms into more quality and quality (Febrian et al., 2021). The use of e-learning in the learning process can present teaching materials that are varied, interactive, and tailored to the needs of students (Nazhifah & Fathurohman, 2023). E-learning can help students to be involved and active in the learning process (Indrayana & Sadikin, 2020). Learners can provide opinions, respond to learning, and design and investigate problems in physics through their efforts (Astuti & Febrian, 2019). E-learning facilitates interaction between students and teachers in teaching and learning activities (Nazhifah & Fathurohman, 2023). Then they can share information about various things related to subject matter and students' self-development needs. So, the development of e-learning becomes a new need in the implementation of learning activities in the classroom, supporting the improvement of students' creative thinking skills and the implementation of the independent curriculum.

E-learning can deliver interactive, engaging, effective, and efficient learning (Aboagye et al., 2020; Wiyono et al., 2020, 2022). Then it is supported by a STEM approach that makes learning much more contextual and sees a problem from various disciplines (Pangesti & Triyanta, 2022; Simeon et al., 2022). So that it can train and improve the creative thinking skills of students. This is what underlies researchers to research the development of STEM-based renewable energy e-learning to improve the creative thinking skills of high school students.

Several studies have been conducted on the development of STEM-based e-learning on the improvement of 21st-century skills of learners, especially in communication and collaboration skills on wave materials (Sury et al., 2022; Wiyono et al., 2022). Then there is research that produces valid and practical STEM-based e-learning products and can improve students' critical thinking skills in science learning (Rahayu et al., 2022) and electrodynamic materials (Wiyono et al., 2020). Then some studies integrate

STEM in flip classrooms to improve students' thinking skills (Aspridanel et al., 2022). However, there has been no research on the suitability of the *Merdeka* Curriculum with ESD STEM to improve students' creative thinking. In particular, no learning resources support the implementation of learning that is in line with the *Merdeka* Curriculum, STEM, and ESD that support the improvement of these skills. Therefore, in this study, *Merdeka* Curriculum learning resources will be developed in the form of STEM-based e-learning on renewable energy topic to improve the creative thinking skills of high school students.

Method

The research was conducted as a developmental study that aims to produce a product in the form of STEM-based renewable energy e-learning to improve the creative thinking skills of high school students. The research subjects were students of class X of SMAN 2 Palembang in the even semester of the 2022/2023 school year. The research process was conducted offline and online using the Alessi and Trollip development models (Alessi & Trollip, 2001).

This research procedure consists of three stages, namely: 1) the planning stage, 2) the design stage, and 3) the development stage (Alessi & Trollip, 2001; Wiyono et al., 2022). In the planning stage, everything needed in the implementation of research is prepared, such as: needs analysis (preliminary study), literature study, time and place of research, materials, and problems in research. At the design stage, which focuses on the e-learning design process to be developed. Starting with developing initial ideas, developing topics, drafting drafts, making storyboards, and preparing materials or documents in the form of text, images, audio, video, and animation are included in e-learning. In addition, it also arranges instruments to measure students' creative thinking skills on renewable energy materials. Next is the development stage, which is the process of realizing the product development plan, conducting alpha testing to determine the feasibility of the product, and then the product that has been eligible for beta testing to see if the product can be accepted by students. So that the product is developed based on the point of view of the user (Learner). The procedure for developing stem-based e-learning of renewable energy materials using the Alessi and Trollip development model can be briefly seen in Figure 1.

Techniques analysis of research data on the alpha test and beta test refers to the evaluation according to Alessi and Trollip (Alessi & Trollip, 2001). The resulting product is classified as a feasible and acceptable category if all aspects of the validation sheet and student questionnaire sheet are acceptable or have reached 100%. In the alpha test, the validator assessment results data on the validation sheet are declared valid if the percentage can be accepted by 100%. This means that all aspects of the validation sheet are acceptable. If there are aspects that are declared to need revision, then these aspects will be improved until they are declared feasible and acceptable by the validator. Then in the beta test, data was collected using a questionnaire. The questionnaire is used by students to assess the practicality of the products that have been developed. The analysis of the questionnaire data used refers to the Aleesi and Trollip evaluation forms. E-learning products are declared practical if all aspects on the questionnaire sheet have reached 100%. If there are aspects in the student response questionnaire that need to be revised, improvements are made until it is declared acceptable for students to use STEM-based renewable energy e-learning that has been declared feasible before.

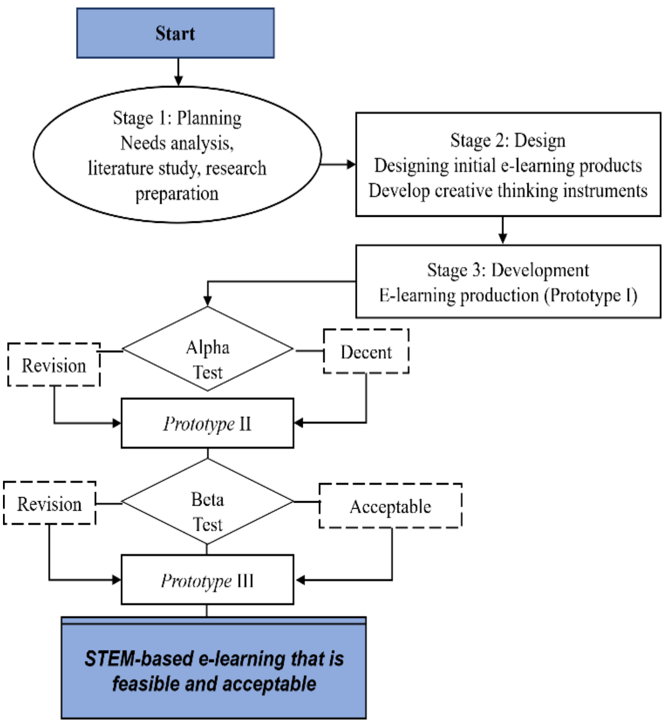

Figure 2. Development Research Flow

Result and Discussion

STEM-based e-learning is a product produced in this study. STEM-based e-learning is designed to improve the creative thinking skills of high school students. This product is equipped with attendance lists, grub chats, learning outcomes, learning objectives, paths of pursuit objectives (ATP), opening (orientation, motivation, and appreciation), supporting information to strengthen understanding of the material, images, and illustrations related to the material, STEM, simulations, evaluations, from discussions and pretest-posttests. The resulting product contains renewable energy material which is a material in Phase E of the even X semester of high school. This research produces STEM-based renewable energy e-learning that is feasible acceptable and effective in improving students' creative thinking skills. Product development is carried out using the Alessi and Trollip development models (Alessi & Trollip, 2001). The results and elaboration of each stage are outlined.

Planning Stage

At the planning stage, the initial analysis was carried out in product development. The results obtained were from four physics materials in Phase E., The most difficult topic to understand according to the perspective of students was renewable energy. Findings in the field show that this can happen due to material problems that are difficult to understand and a lack of learning resources related to the topic of renewable energy. This is in line with Hartanto et al. (2021) who reveals that learning resources that raise the topic of renewable energy are still very minimal it has an impact on students' low mastery of the material.

Other findings at the planning stage related to students' perspectives on the need to apply STEM in physics learning, especially renewable energy materials, are very confident that they can improve their creative thinking skills. STEM learning is carried out through projects that are integrated with various disciplines in everyday life (Pangesti & Triyanta, 2022; Simeon et al., 2022; Sukma & Marianti, 2023). This is in line with the implementation of the *Merdeka* Curriculum which emphasizes more on project-based learning (Triwulandari et al., 2022). So, it is very suitable to be integrated in the process of teaching renewable energy material. This is supported by research by Wahyuaji & Suparman (2018) that reveals that a STEM approach is needed to help students understand concepts and improve thinking skills. This kind of learning is in accordance with the expectations of ESD-based learning criteria (Aina et al., 2023).

Another result of the planning stage is the determination of a suitable LMS Platform that will be used in developing renewable energy e-learning to improve students' creative thinking skills. The selection of models and media used by teachers and the involvement of students in learning play a major role in ESD-based learning (Aina et al., 2023). Therefore, moodle LMS is chosen that can accommodate thesethings. Moodle LMS was chosen for several reasons, including: it is an open source LMS platform that can be used by anyone without the need to incur additional costs for subscription in addition to the internet quota used (Haeruman et al., 2021). Allows learners to access through computers and smartphones, the use of which is more practical and user friendly (Zhao, 2019). There are many choices of features that support the learning process such as tasks, quizzes, chat, collaboration, and the main features that can upload various formats of learning materials and are easier to understand (Herayanti et al., 2017). Through Moodle, teachers can directly assess and download students' work in the form of statistical data in the form of excel spreadsheets (Yana et al., 2019)

The use of Moodle as an open-source LMS in the development of STEM-based renewable energy e-learning helps researchers in classroom settings to facilitate teachers in delivering materials and students in participating in learning activities. In addition, Moodle's use of various selected e-learning platforms aims to create an active (Gunawan et al., 2019) and interactive learning environment (Umiyatun et al., 2020). Active learning environments can support the improvement of students' creative thinking skills (Gunawan et al., 2019; Hermansyah & Herayanti Lovy, 2015). In addition, the use of Moodle e-learning allows teachers and students to exchange information quickly and flexibly, as well as efficient interaction between teachers and students and students with their friends so that learning is more interactive and interesting (Simanullang & Rajagukguk, 2020).

Design Stage

At this stage, the researcher designs the initial product model of physics learning e-learning on renewable energy material, develops topics through the analysis of learning concepts by outlining learning content (GBIP), then prepares a draft in the form of making a flowchart of the initial design of the product that shows the flow in the delivery of material through e-learning which is developed starting from the opening, content and closing, and proceeds with the preparation of a manuscript (Storyboard) containing a description of all the things that will be displayed including instructions or illustrations of e-learning that will be produced and preparing texts, images, videos, audio, animations etc. that are tailored to the material. In addition, the researcher also designed an instrument that will be used to see the potential effects of STEM-based e-learning on students' creative thinking skills. This stage is carried out by analyzing the concept of learning by outlining the learning content of learning development which can be seen in Table 1.

Table 1. Outline of Learning Content

Subject matter	Creative thinking skills indicator	Component STEM	Media
Energy sources	Fluency thinking Flexibility	S, T, M	Learning videos, text, and images
Forms of energy	Elaboration Flexibility	S, T, M	Learning videos, texts, images, and discussion forums
The Law of Conservation of Energy and Energy Conversion	Flexibility Fluency thinking	S, T, E, M	Learning videos, texts, images, simulations, and discussion forums
The urgency of the issue of energy needs	Fluency thinking	S, T, M	Learning videos, text, and images
Energy sources: Renewable and non-renewable energy sources	Flexibility Originality Elaboration	S, T, E	Learning videos, texts, images, and discussion forums
Impact of use and efforts to meet energy needs	Fluency thinking Originality Elaboration	S, T, M	Learning videos, text, and images
Projects	Elaboration	S, T, E	Video, text.

Note:
S : Science.
T : Technology.
E : Engineering
M : Mathematics

The next stage is drafting based on the topic development that has been carried out. At this stage, it starts with the creation of storyboards and flowcharts. The flowchart is made to provide an overview of the menu or features contained in e-learning. Then, the researcher also made a storyboard that was used as a guide in the process of developing STEM-based renewable energy e-learning. Storyboard is an overview of the forms and presentations that will be displayed on e-learning by the outline of the contents of e-learning that has been made before. Flowcharts and e-learning storyboards can be seen in the appendix. After the flowchart and storyboard are completed, the researcher then prepares learning materials in the form of text, images, tables, videos, animations, links, and simulations that will be used in developing the product.

Development stage

This stage is the development stage of STEM-based renewable energy e-learning. At this stage, it begins by making an e-learning prototype by the initial design, then conducting alpha testing and beta testing. The results of this stage are described as follows.

Results of the E-learning Development Stage

In this stage, researchers made a prototype of STEM-based renewable energy e-learning the design at the design stage. After the learning materials in the form of text, images, videos, animations, links, and simulations to be used were successfully developed with the help of applications such as Filmora and Canva to improve the quality of presentation. The process of developing the prototype I of STEM-based renewable energy e-learning was developed with the help of Moodle which can be accessed through the link. The learning process in renewable energy e-learning is divided into four meetings. At every meeting, there is material in the form of text, images, and learning videos embedded from YouTube. In addition, there is a discussion form that contains problems related to renewable energy materials as one of the processes to improve students' creative thinking skills.

There are also virtual simulations sourced from PhET Simulation so that they can be used by students independently or in groups to practice creative thinking skills and understand the subject matter. Then in each meeting, there is a assessment containing questions that have been developed based on four aspects of creative thinking (fluency, flexibility, originality, elaboration) and STEM approaches. The assessment plays a major role in training students' creative thinking skills (Faresta et al., 2020). Furthermore, at the end of the learning, a project assignment has been prepared where the task indicates that the learning has been carried out using a STEM approach (Triana et al., 2020). Figure 2 shows the appearance of the prototype I of STEM-based renewable energy e-learning.

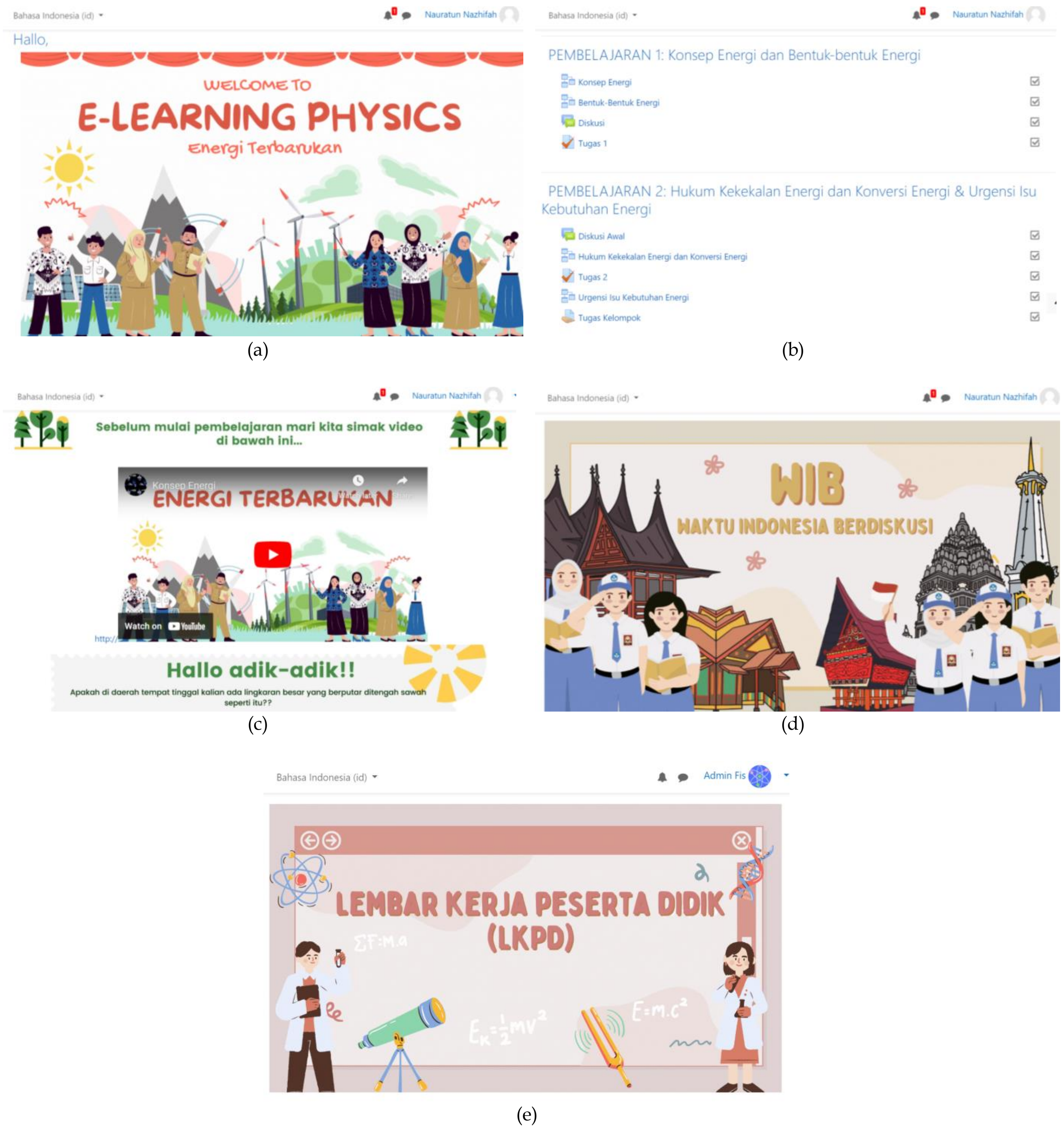

Figure 2 Display of Prototype 1 e-learning (a) Welcome speech; (b) Learning Activities 1 and 2; (c) Material content; (d) discussion; (e) Project

The follow-up of this stage is the alpha test and beta test of prototype I of STEM-based renewable energy e-learning to improve the creative thinking skills of students who aim to produce a viable product based on experts and acceptable based on users (students).

Alpha Test Result

The alpha test stage was carried out to see the feasibility of STEM-based renewable energy e-learning to improve students' creative thinking skills. The feasibility test was carried out on three aspects, including: content, learning design, and e-learning. The content expert is an expert in the field of physics material and is one of the lecturers in the Master of Physics Education Study Program, Universitas Sriwijaya. The learning design expert is one of the lecturers in the Master of Physics Education Study Program, Universitas Sriwijaya. The media expert (e-learning) is one of the lecturers of the Master of Education Technology Study Program, Universitas Sriwijaya. Every aspect of the feasibility test is carried out through two cycles with several components that the researcher needs to add or improve. The results of the alpha test can be seen in Table 2.

Table 2. Alpa Test Assessment Results

Aspect	Indicators	Percentage Alpha test 1	Alpha test 2
Content	The suitability of the material on e-learning with the curriculum field	100	100
E-Learning	Product fit with creative thinking skills	50	100
	Conformity of the product with concept mastery	100	100
	Compatibility with material coverage	100	100
	Compliance with STEM elements	100	100
	Average percentage	90	100
Media	Interactivity	66,8	100
E-Learning	independence.	100	100
	Accessibility	100	100
	Enrichment	100	100
	Average percentage	91.7	100
Learning	Compatibility with learning devices (opening)	25	100
Design	Compatibility with learning tools (core)	85.8	100
	Compatibility with learning devices (closing)	100	100
	Average percentage	70.3	100

Table 2 shows that the alpha test consists of two cycles in each aspect of the matter because all aspects assessed have not been 100% declared acceptable. In the content aspect of STEM-based renewable energy e-learning, the average score is 90%. Then in the media aspect (e-learning), the average value was 91.7%. Meanwhile, the learning design aspect obtained an average of 70.3%. This is what underlies the need for improvements in e-learning. Validators also provide comments and suggestions related to e-learning products developed by researchers as materials for improvement. Improvement is very important in order to produce suitable and useful products in classroom learning (Kurniawan et al., 2018; Sukma & Marianti, 2023). After the improvement of the product and the second step of the alpha test, it is known that STEM-based renewable energy e-learning is declared 100% acceptable so that it is feasible to use.

Beta Test Results

The beta test is carried out to see whether the developed product can be accepted based on the user's point of view in this case students by using a student response questionnaire sheet. At the beta test stage, the researcher took a sample of 9 students at random with different levels of ability. Learners are given the opportunity to try using stem-based renewable energy e-learning to improve creative thinking skills. The beta test results can be seen in Table 3.

Table 3. Learner Questionnaire Filling Results at the Beta Test Stage

Statement	Beta test average
The display of text/reading in e-learning is clearly readable	88.89
Learners enjoy learning the physics of STEM-based renewable energy materials with e-learning.	66.67
The narrative contained in e-learningis easy to understand.	100.00
The videos contained in e-learningare easy to understand.	88.89
The simulations contained in e-learningare easy to use.	100.00
Images on e-learning help students understand renewable energy materials.	88.89
The material contained in e-learning helps students understand renewable energy material.	77.78
The links available in e-learning can be accessed easily.	55.56
The question exercises available in e-learning help students understand physics concepts.	100.00
The discussion forum contained in e-learning makes it easier for students to discuss with teachers and classmates.	88.89
The text or description of the material contained in e-learning helps students in improving creative thinking skills.	100.00
Activities using simulations in groups contained in e-learning help in improving creative thinking skills.	100.00
The use of discussion forums contained in e-learning helps improve creative thinking skills	100.00
Average Percentage	89.6

Based on Table 3 data, the results of students' responses to STEM-based renewable energy e-learning to measure students' creative thinking skills showed that it was acceptable at 89.6%. In addition, at this stage there are comments and suggestions given by students to be used as a reference in product improvement can be seen in Table 4.

Table 4. Learner Comments and Suggestions in the Beta Test Stage

Student name	Comment	Description
NS	- The text display is clearly legible and understandable. - The learning videos available are easy to understand	No revisions
CB	- Using this e-learning makes it easy for me to understand the material presented	No revisions
MSM	- There are photos that are not clear enough.	Revision
MD	- Using the available learning videos helps me to more easily understand renewable energy materials - Thank you for introducing us to stem-basede-learning, we really feel facilitated in the implementation of learning.	No revisions
USA	- I still find it difficult to use e-learning, especially in using thefeatures in it. - There is material that I still don't really understand because I think it lacks detail.	Revision

Based on Table 4 data, a beta test was then carried out in the second stage according to the suggestions and comments. Beta test results in the second stage obtained an average of 100%. This shows that stem-based renewable energy e-learning to improve creative thinking skills is acceptable from the user side in this case students. So the prototype I developed has been declared feasible and acceptable with a percentage of 100% after the alpha test and beta test in two cycles or other words the e-learning is feasible according to experts and acceptable according to users. These data show that stem-based renewable energy e-learning that has been developed can help students and teachers in physics learning so that they can easily understand physics concepts and improve students' creative thinking skills. In addition, many more conveniences are presented in order to improve the creative thinking skills of peseta students such as the existence of discussion forms, simulations, and learning videos (Nurhaisa et al., 2023).

The results of these findings are in line with several previous studies that also produce similar products, produce stem-based e-learning of static fluid material that is very feasible and acceptable for use (Syafei et al., 2020), E-schoology of vibration and wave material that is developed valid and practical so that it is feasible for use in science learning in junior high school (Hartanto et al., 2021), Moodle-based e-learning developed in the category according to all aspects, effective and practical, so that it is feasible for use in physics learning (Yusuf et al., 2020), valid and practical e-learning-based distance learning design (Martini et al., 2021), as well as e-learning material of wave characteristics and mechanical waves that are feasible and acceptable (Hidayah et al., 2022; Sury et al., 2022).

Conclusion

Based on the research that has been carried out, it can be concluded that STEM-based renewable energy e-learning to improve the creative thinking skills of students developed is declared feasible to use with 100% acceptable percentage and 100% acceptable percentage. So that STEM-based renewable energy e-learning can be used in the learning process for the effectiveness test stage.

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Conceptualization, N. N, K. W, I.; methodology, N. N, K. W, I.; validation, K.W and I.; formal analysis, N. N.; investigation, N. N.; resources, N.N.; data curation, N. N.; writing—original draft preparation, N. N.; writing—review and editing, N. N, K. W, I.; visualization, N.N. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest
The author declares that there is no conflict of interest regarding the writing and publication of this paper.

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