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PROBLEM-BASED E-MODULE INTEGRATED WITH STEM AND ASSISTED BY LMS TO FOSTER CREATIVE THINKING ABILITY

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ABSTRACT

Appropriate learning resources are required when delivering problem-based physics materials integrated with STEM (Science, Technology, Engineering, and Mathematics). This research aims to create a valid, practical, and effective problem-based e-module integrated with STEM and supported by an LMS (Learning Management System) to train creative thinking skills on harmonic vibration material. The 4-D development model was used in this research (define, design, development, and disseminate). The study of tenth-grade students from class MIA 1 at SMA Muhammadiyah 1 Purbolinggo revealed that the developed e-module had a content validity test result of 89 % and a constructs test result of 88%. The practicality test of the readability aspect yielded an 80% result, and the implementation yielded a 79.07% result. Furthermore, the n-gain value for the effectiveness test based on improvement was 0.54 in the medium category. Furthermore, there was a difference in average pretest and posttest scores with less than 0.05. It is possible to conclude that the developed e-module is appropriate for training students' creative thinking skills. Further researchers are expected to develop platform-assisted e-modules that are more interactive and easier to use in future research.

E-MODUL BERBASIS MASALAH TERINTEGRASI STEM BERBANTUAN LMS UNTUK MELATIH KETERAMPILAN BERPIKIR KREATIF

Kata Kunci:

E-modul
Keterampilan berpikir kreatif
Learning management system
STEM

ABSTRAK

Dalam menyampaikan materi fisika berbasis masalah terintegrasi STEM (*science*, *technology*, *engineering*, *and mathematics*) diperlukan sumber belajar yang tepat. Penelitian ini bertujuan untuk mengembangkan e-modul berbasis masalah terintegrasi STEM berbantuan LMS (*learning management system)* yang valid, praktis, dan efektif untuk melatih keterampilan berpikir kreatif pada materi getaran harmonis. Penelitian ini menggunakan desain pengembangan model 4-D (*define, design, development, and disseminate)*. Hasil penelitian di kelas X MIA 1 SMA Muhammadiyah 1 Purbolinggo menunjukkan bahwa e-modul yang dikembangkan memiliki hasil uji validitas isi 89% dan konstruk 88%, hasil uji kepraktisan aspek keterbacaan 80% dan keterlaksanaan 79,07%, dan hasil uji efektivitas berdasarkan peningkatan nilai n-gain sebesar 0,54 dengan kategori sedang. Selian itu, terdapat perbedaan nilai rata-rata *pretest* dan *posttest* dengan signifikansi lebih kecil dari 0,05. Dapat disimpulkan

bahwa, e-modul yang dikembangakn layak digunakan dalam untuk melatih keterampilan berpikir kreatif siswa. Untuk penelitian selanjutnya, diharapkan untuk mengembangkan e-modul berbantuan *platform* yang lebih interaktif dan lebih mudah digunakan.

1. INTRODUCTION

Technological advances in the twenty-first century have permeated many aspects of life, including education. Teachers and students, lecturers and students, and educators and students are expected to have teaching and learning skills [1]. In the twenty-first century, five skills must be trained and developed: problem-solving skills, communication skills, collaborative skills, critical thinking skills, and creative thinking skills [2]. Creative thinking is students' ability to use their imaginations to generate ideas, ask questions, formulate hypotheses, experiment with alternative solutions, and evaluate [3]. Furthermore, creative thinking is the ability to consider numerous possible solutions to problems [4]. Students with a high level of creative thinking are motivated and enthusiastic about learning [5]. Learning requires a learning spirit, which is essential when studying physics.

Harmonic vibrations are one of the physics topics that students struggle with. The results of a recapitulation of the needs analysis of high school students in Lampung show that 92.5%t of 40 students have difficulty understanding material whose concepts are abstract, making it inappropriate for problem-solving. This is consistent with previous research, which shows that students still struggle to understand and generate ideas from a given problem [6]. Students struggle with relating the concept to the problem presented and identifying the parameters required to solve the problem [7]. Furthermore, 75% of the 16 teachers stated in the recapitulation of teacher needs analysis that they had measured students' creative thinking skills and allegedly had low creative thinking skills because students were less active in expressing ideas. Furthermore, students are less able to solve problems involving physical phenomena and are constantly fixated on formula-based solutions [8]. The problem-based learning model is one of the learning models that is expected to be able to overcome these issues [9].

Problem-based learning has four characteristics: student involvement in problem-solving steps, investigations in exploring the information needed, performance in presenting findings, and reflection on the problems discussed [10]. Curiosity and conceptual understanding drive student activity in problem-based learning [11]. According to previous research, problem-based learning can improve students' problem-solving abilities [12] and creative thinking abilities [13].

A learning approach that supports the learning process, such as the STEM approach, is required in addition to the learning model. STEM is very popular in education because it is required for honing cognitive skills, manipulating, designing, utilizing technology, and applying knowledge [14]. The PBL model with the STEM approach fosters student creativity through problem-solving processes in everyday life [15]. In addition to guiding students to solve problems given in groups, it allows students to work together and manage discussion patterns that match the circumstances of their respective groups [16].

Appropriate learning resources are required when delivering STEM-integrated problem-based physics materials. E-module is a suitable STEM integrated learning resource [17], [18]. According to the findings of a recapitulation of the needs analysis of teachers and students on the use of learning media, (1) 87.5% of teachers use printed

books from schools, (2) 92.5% of students require e-modules equipped with STEM-integrated images and videos, and (3) 100% of students have smartphones. This fact demonstrates that the technology available to students is adequate for learning. One approach to overcoming these issues is to create an appealing and functional e-module. E-modules are non-printed teaching materials that can help students learn [19] to learn actively and independently [20]. Because there are learning instructions and concepts, e-modules can insert pictures or videos to help students understand teaching materials [21]. Good conceptual understanding indicates good creative thinking skills [22], allowing them to practice creative thinking skills [23]. The learning situation and conditions have improved since the Covid-19 pandemic, thanks to the LMS (Learning Management System), one of which is Google Classroom. Thanks to technological innovations like Google Classroom that can be used on laptops and mobile phones. Using a learning management system (LMS) such as Google Classroom in the classroom can boost learning motivation and improve student learning outcomes [24]. Learning outcomes contribute positively to creative thinking [25].

Several studies have been conducted on the development of e-modules to improve creative thinking skills, including realistic-based e-modules to improve creative thinking using the Kvisoft Flipbook Maker Pro application [26], e-modules with Flip PDF Professional software to improve creative thinking skills [27], PJBL-based e-modules to develop students' creative thinking [28], e-modules to train understanding of physics concepts using the 3D Page Flip Multimaker Pro [29], and e-modules to stimulate HOTS with a STEM approach using the 3D Page Flip Multimaker Pro application [18]. However, no research on problem-based e-modules integrated with STEM using the LMS-assisted Canva application to practice creative thinking skills has been conducted. This research aims to create a valid, practical, and effective problem-based e-module integrated with STEM using the LMS-assisted Canva application to train creative thinking skills on harmonic vibrations.

2. METHOD

This research is research and development, referring to Thiagarajan's 4D development model (define, design, develop, and disseminate stages) [30]. The product developed in this study was a problem-based physics e-module integrated with STEM and assisted by LMS to practice creative thinking skills. The research took place at SMA Muhammadiyah 1 Purbolinggo. This research was carried out during the second semester of the 2021/2022 academic year. In this study, 30 students from class X MIA 1 participated in a large group trial. Figure 1 depicts the steps of this research.

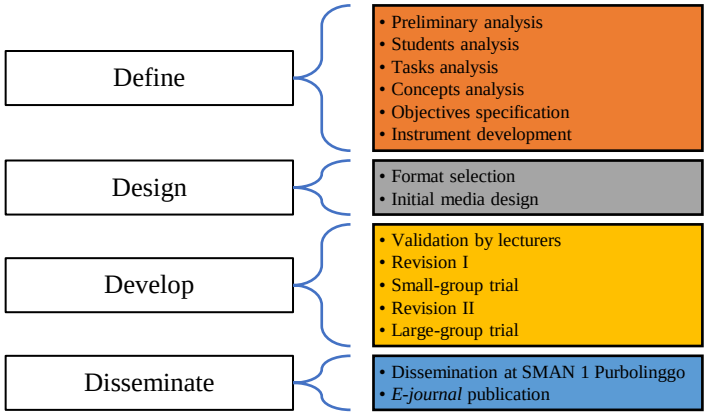


Figure 1. The Procedure of Research

The instruments used in this research were content validation and construct validations questionnaires, e-module readability tests, and student response questionnaires. The data analysis techniques involved were the normality test, expert team validation test, and e-module readability analysis. Using the SPSS version 17 program, the normality test was performed to determine whether the data were normally distributed. If the significance was more than 0.05, the calculation results indicated that the data were normally distributed [31].

Table 1 shows the validation test performed by the expert team on the content and construct aspects of the e-module, whose feasibility was assessed using a questionnaire based on the Likert scale.

Table 1. Likert Scale

Score	Criteria
5	Strongly agree
4	Agree
3	Less agree
2	Disagree
1	Strongly disagree

The following formula analyzed the score:

$$P = \frac{Total\ score\ obtained}{maximum\ score} \times 100\% \qquad (1)$$

The interpretation of the Likert scale in Table 2 is provided as a provision for making decisions based on the results of the calculations.

Table 2. Likert Scale Interpretation

Percentage	Description
81%-100%	Highly feasible
61%-80%	Feasible
41%-60%	Quite feasible
21%-40%	Less feasible
0%-20%	Not feasible

The students' test results determine the readability of the e-module. The formula used to analyze the e-module readability test results is:

$$M = \frac{\sum X}{N} \qquad (2)$$

A Likert scale questionnaire was used to analyze student responses to the e-module. The formula used to present the data collected from all students is:

$$Score = \frac{Students' total\ score}{Maximum\ score} \times 100\% \ (3)$$

The scores that have been obtained were then converted into the categories in Table 2.

3. RESULTS AND DISCUSSION

This development research produced teaching materials in the form of an integrated problem-based physics e-module integrated with STEM to practice creative thinking skills. The teaching materials were developed in line with the 4D research procedure,

which included the define, design, develop, and disseminate stages. The outcomes of each stage are as follows.

3.1 The Define Stage

This stage includes a series of needs in learning physics that consists of five steps: preliminary analysis, student analysis, task analysis, concept analysis, and learning objective specification. The preliminary analysis was carried out through literature and field studies. The literature review findings were obtained by reviewing several articles related to quality teaching material information to practice creative thinking skills. The findings of field studies conducted by providing online questionnaires to physics teachers revealed that 87.5% of 40 teachers used printed books from school, which made it difficult for students to understand the material because the teaching materials cannot be visualized. Furthermore, 87.5% of the 40 teachers had never used e-modules with videos and images delivered via LMS. Based on the findings, the teacher required teaching materials that include images and videos and are delivered via the LMS to make it easier to explain physics material.

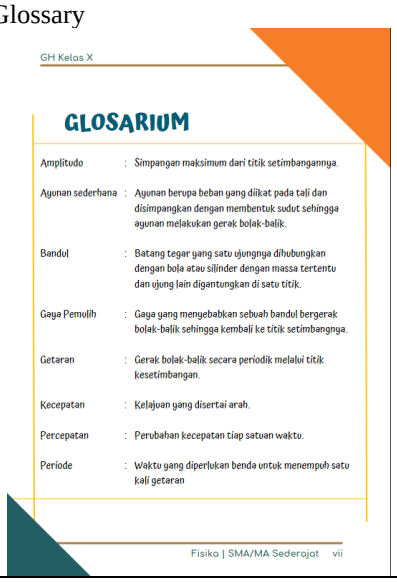
Furthermore, student analysis revealed that 55% of 40 students were disinterested in common teaching materials used in the learning process because most learning activities consist of only reading, listening to the teacher's explanation, and working on questions. As a result, students require teaching materials that present physical phenomena and learning activities that engage students and make them active participants in the learning process.

The following steps were the concept analysis, task analysis, and learning objective specification. Harmonic vibrations are taught in this case, including vibrations on pendulums, vibrations on springs, and harmonic vibration analysis. The analysis of core competencies and essential competencies was used to specify learning objectives (KD). On the material of harmonic vibration, the chosen KD were 3.11 and 4.11. According to interviews with physics teachers, the limitations of tools and practicum materials in schools continue to keep skills in conducting practicals low. As a result, students were included in experimental activities that can train creative thinking skills during the learning process. Based on this data, the material for harmonic vibrations was an excellent material to be developed.

3.2 The Design Stage

Cover, Francis page, introduction, table of contents, concept map, glossary, instructions for using e-modules, competencies, material descriptions, summaries, STEM activities, sample questions, practice questions, evaluations, and bibliography, were the outcomes of the Design stage of the physics e-module draft. This stage was completed by dividing the material's structure according to the achievement indicators at each meeting. After completing the material structure, storyboard creation, and e-module creation on the Canva platform, the researchers created the e-module design as an early development product. It was decided to design a draft of the e-module writing framework to make it easier to compile the contents of the e-module and sort the components. Following the formation of the e-module framework, the e-module was developed using Canva, then distributed on a link posted on the LMS. This e-module can be accessed offline in a pdf file and online as a free link. Table 3 shows the storyboard for the developed e-module.

Table 3. The Storyboard of the Problem-Based E-module Integrated with STEM

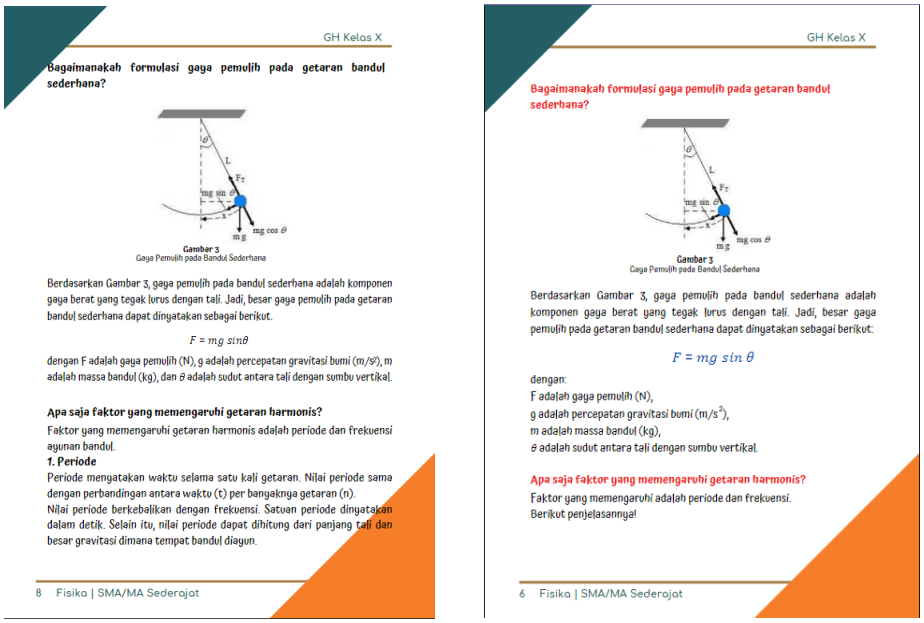
No	Display	Description
1	Cover 	The cover includes: - The title - Image related to harmonious vibration - Subject - Class and grade - Author
2	Concept map 	The concept map contains the harmonious vibration sub-chapters of learning activities 1, 2, and 3.
3	Glossary 	The glossary contains some crucial terms in the harmonic vibrations chapters.

4	Learning activities		The learning activities 1, 2, and 3 contain: - The purpose of the learning activities - A description of the material in which there are related pictures and videos.
5	Activities		The e-module activities in each learning activity contain: - Activity 1, STEM-based material on the pendulum swing (science) - Activity 2, STEM-based pendulum swing material (engineering and technology), - Activity 3, Stem-based material for pendulum swings (mathematics).

In the next stage, the researchers developed the instrument to validate the e-module.

3.3 The Development Stage

The researchers began developing the e-module at this point. Storyboards were used to guide the development of the e-module. The Canva app was used to create the e-module. Following the creation of the e-module, the next stage was validation by the material and media experts. The validator determined that the e-module could be used without revision and could proceed to the field trial stage. The media experts suggested changing the color of writing on essential explanations. Figures 2 depict these changes.



(a) (b)

Figure 2. (a) Before Revision and (b) After revision

Small group individual trials were conducted through a questionnaire on ten students of class X MIA 2. The results of the questionnaire data analysis can be seen in Table 4.

Table 4. The Data Analysis of the Small-Group Trial

No	Statements	Numbers	Percentage
1	E-module is important for me	8	80%
2	The description of the material for each learning activity is relevant to the objectives of the learning activities to be achieved	7	70%
3	Images and videos on the e-module help me understand the material	8	80%
4	Instructions/guides make it easy to operate the e-module	8	80%
5	The presentation flow makes the e-module easy to understand	8	80%
6	The clarity of the content of the e-module makes learning easier	8	80%
7	E-modules make me interested in learning	9	90%
8	Practice questions are suitable for the material	8	80%

The following step was to conduct a large-group trial with 30 students from class X MIA 1. The large-group trial was conducted using a questionnaire to determine students' responses to the e-module. Table 5 shows the findings of the analysis.

Table 5. The Data Analysis of the Large-Group Trial

No	Questions	Numbers	Percentage
1	Can e-modules be used?	30	100%
2	Does the appearance of the e-module make you interested in learning?	28	93%
3	Is the language used in the description of the material easy to understand?	26	86%
4	Is the sound of the video heard clearly?	28	93%
5	Does the overall format of the e-module encourage you to come up with ideas?	28	93%
6	Are reflection questions understandable and answered?	25	83%
7	Does the presentation flow make it easier for you to understand the e-module?	26	86%

8	Do the pictures and videos make it easy for you to learn using the e-module?	27	90%

The large group trial stage included pretest and posttest to assess students' creative thinking skills. Before beginning the lesson, five pretest questions about harmonic vibrations were given to determine the initial ability before using the e-module. The following is an example of a student's pretest questions and answers.

Table 6. Questions and Students' Answers

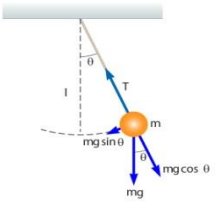
No	Questions	Students' Answer
1	An old clock is an application of harmonic vibrations in real life. The pendulum of the clock moves periodically. From this statement, determine: a. Why did it happen? b. Analysis of the image of the force acting on the pendulum! c. Give a conclusion from the factors that affect the movement of the pendulum clock!	a. Because it is given a battery, the clock's energy source is a battery that can move the clock's pendulum. b. – c. Battery, hour hand, period, frequency
2	We often encounter harmonic vibrations in life. One of them is a children's swing. If the rope in the swing can be shortened and lengthened, what is the relationship between the length of the rope and the period? Give your assumption if a child wants the swing to return to its original place quickly!	The shorter the rope, the greater the swing period. By shortening the rope so that the swing stops quickly

The pretest results revealed that 1) 83% of students cannot represent images into physics ideas, 2) 90% of students cannot express their opinions in writing, and 3) 10% of students can formulate arguments and define terms. These results were obtained because students have never had the opportunity to compile and reconstruct the information they have obtained [32], so their problem-solving ability has not been trained.

The researchers began the treatment at the first meeting after receiving the pretest results by dividing the students into six groups of five. Then, the researchers distributed the e-module link in the LMS. Furthermore, the e-module was displayed in front of the class. The learning began by providing an understanding of the pendulum swing, which consisted of 15 pendulums with the same mass and different lengths of string that can form a harmonious pendulum movement.

Following the presentation, several prerequisite questions were presented in the e-module to be answered together. The students in each group were then asked to draw an analysis of the forces formed on the pendulum swing. They were asked to read a description accompanied by pictures after they had constructed their understanding of the factors that affected the motion of a pendulum. Following comprehension of the description, the students were asked to predict the questions presented, conducted experiments, and created a pendulum swing design to be used as a conclusion. The researchers administered posttest questions at the third meeting to assess students' abilities after learning with the e-module. The following are examples of student questions and answers from the posttest.

Table 7. Questions and Students' Answers

No	Questions	Students' Answer
1	An old clock is an application of harmonic vibrations in real life. The pendulum of the clock moves periodically. From this statement, determine: a. Why did it happen? b. Analysis of the image of the force acting on the pendulum! c. Give a conclusion from the factors that affect the movement of the pendulum clock!	a. Because the pendulum of the clock always swings past the equilibrium point  b. Battery, period, frequency
2	We often encounter harmonic vibrations in life. One of them is a children's swing. If the rope in the swing can be shortened and lengthened. a. What is the relationship between the length of the rope and the period? b. Give your assumption if a child wants the swing to return to its original place quickly!	The length of the rope is directly proportional to the period. The shorter the rope, the greater the swing period. By shortening the rope swing to quickly return to its original place.

According to the posttest results, 1) 90% of students could represent images into physics ideas, 2) 93% of students could explain their opinions in writing, and 3) 100% of students could formulate arguments and definitions. The student's ability to answer questions was better than before because they were allowed to compile and reconstruct the information they had obtained. With the opportunity, the students could make a representation [32], and thus students can answer the questions well.

Research has shown that problem-based physics learning can improve students' critical and creative thinking skills [34]. Learning activities include looking at pictures and videos, making predictions, experimenting, and concluding. The developed e-module contains problem-based harmonic vibrations material integrated with STEM on the four aspects of creative thinking skills: fluency, flexibility, originality, and elaboration [33].

The developed e-module covers the a) science, in which students are asked to observe an image or video. Because videos make learning activities more interesting, science (STEM) can be stimulated [35]. Following the observation, students predicted the phenomena displayed. Fluency in the sub-indicator of the ability to generate many ideas is linked to making predictions into indicators of creative thinking. b) Engineering and technology, in this section, students designed a simple tool from existing materials and experimented directly to train the engineering and technology (STEM) aspects [36]. The link between design and existing material tools is a flexible thinking skill in the indicator sub-chapter of the ability to propose a variety of problem-solving. In addition to designing, students conducted direct experiments to test their predictions. The evidence for his predictions was included in the creative thinking indicator, specifical originality in the sub-indicator of the ability to provide relatively new ideas that most people rarely provide. c) Mathematics, in this section, students collected data in the form of formulas and related information to solve problems, which can be used to practice mathematics (STEM) [37]. Collecting this data was included in the creative thinking indicator, specifically elaboration skills on the sub-indicators ability to detail data-driven answers.

After collecting the pretest and posttest data, SPSS 17 was used to determine whether the data were normally distributed or not. Table 8 shows the results of the student's normality test.

Table 8. The Results of the Normality Test

Data	Assymp. Sig	Description
Pretest	0,200	Normal
Posttest	0,200	Normal

Then, the average n-gain score was used to see if there was an increase in students' creative thinking skills.

Table 9. The Average N-gain Score

N-gain Value	Category
0,54	Medium

The developed e-module was suitable for conveying harmonic vibration material because it contains images, videos, and material explanations, making students more interested in learning rather than using textbooks. This finding is consistent with previous research, which found that the benefits of e-modules include students being pleased and interested in learning [20]. Another research found that e-modules can help with creative thinking [28].

3.4 The Dissemination Stage

The dissemination stage consisted of the dissemination and final stage of this research and development. The researchers distributed the e-module link to physics teachers at SMA Muhammadiyah 1 Purbolinggo. The students felt engaged and capable of learning independently using the e-module [37]. Furthermore, the e-module served as a resource for learning, particularly for harmonic vibrations. The findings of this research were also published in the Indonesian Journal of Science and Mathematics Education as scientific articles.

4. CONCLUSION

The findings demonstrated that the developed problem-based physics e-module integrated with STEM assisted by LMS was valid, practical, and effective. It is highly feasible in terms of content (89%) and constructs (88%) in the e-module validity test. The result of the practicality test of the readability aspect was 80%, and the implementation was 79.07%. The effectiveness test results can be seen through the increase in the n-gain value of 0.54 with a moderate category. Furthermore, there was a difference in the pretest and posttest average values with a significance of 0.05. It is possible to conclude that the developed e-module is appropriate for training students' creative thinking skills. It is hoped that future research will create more interactive and user-friendly platform-assisted e-modules.

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