Jurnal Pendidikan Fisika dan Keilmuan (JPFK)
Vol. 9, No 1. March 2023, pp. 53-65
P-ISSN: 2442-8868, E-ISSN: 2442-904X, DOI: http://doi.org/10.25273/jpfk.v9i1.13261

Development of Electronic Modules based on Science, Technology, Engineering and Mathematical (STEM) Approaches in Vibration and Wave Courses

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Abstract

This study aims to produce vibration and wave teaching materials in electronic modules based on the STEM approach. This study uses research and development methods with a 4D development model. The research subjects were all Physics Education study program students who took vibration and wave courses. Data collection tools include validation sheets (materials and media), response questionnaires to measure the practicality of the module, and tests to measure the module's effectiveness. The data analysis technique uses proportions with predetermined criteria and practicality. The effect size equation is used to measure the module's effectiveness. The results showed that (1) the e-module was feasible to use according to the expert with an average value of 3.77 material and media validation results and 3.86 very valid categories; (2) the practicality of the e-module with a very practical category is 76.75% and (3) the effectiveness of the e-module in increasing the HOTS of students with the criteria is very effective.

Keywords: electronic module, vibration and waves, higher-order-thinking skills

How to Cite: Saputri, D.F., Wahyudi., Nurhayati., Nurussaniah. (2023). Development of Electronic Modules based on Science, Technology, Engineering and Mathematical (STEM) Approaches in Vibration and Wave Courses. *Jurnal Pendidikan Fisika dan Keilmuan (JPFK)*, 9(1), 53-65. http://doi.org/10.25273/jpfk.v9i1.13261

Introduction

In the era of the Industrial Revolution 4.0, changes occurred in every aspect of life. The use of technology in this era causes a paradigm shift in society, especially in obtaining information (Darmawan, 2014). Technological developments also have a significant impact on the field of education. Education is a process of communication and information from educators to students that contain educational information through the media to present ideas, ideas, and educational materials, as well as the students themselves. The success of education is closely related to the learning process. In the current technological era, learning no longer has to go through a face-to-face process (offline) but can also be done through a virtual face-to-face process (online). Zhang et al. (2017) stated that innovative learning resources that can be used by students anywhere and anytime are needed by students today. This was also conveyed by (Suastika & Triwahyuningtyas, 2019) statement that quality electronic teaching materials are needed in online learning.

The results of interviews with lecturers who are effective vibration subjects show that the learning resources used are printed book modules with an average number of more than 100 pages. This makes students too heavy to carry during lectures and away from the impression of technology-based learning. Characteristics of quality teaching materials, namely (1) can be used independently by students both in the learning process and outside the learning process; (2) compiled systematically and completely; (3) following the times, especially technology and knowledge; and (4) designed in a language that is easily accessible to students. Especially at this time, the Ministry of Education and Culture encourages all universities to be able to implement online learning. This is also stated in the Educational Plan regarding an independent campus, one of which is to use practical and economic learning resources that students can use at any time. Therefore, quality teaching materials are needed to make it easier for students to understand the material being studied.

One of the important teaching materials in learning is the learning module. Ferdianto et al. (2019) stated that the use of modules in learning aroused students' interest in learning and made it easier for students to understand concepts through the systematic steps contained in the modules. The module can be in print and can also be transformed into an electronic form of presentation so that it is called an electronic module (e-module). E-module is a form of self-study material that is systematically arranged and is displayed in an electronic format, in which there is audio, animation, and navigation (Sugianto et al., 2013). Ariyanti et al. (2019) states that e-modules are a combination of print and computer media so that they can present information in a structured, attractive manner and have a high level of interactivity. Through these e-modules, students can carry out independent learning without the time and place restrictions. Several studies have developed learning e-modules that impact improving students' skills and learning outcomes. Serevina et al. (2018) developed an effective PBL-based e-module to improve science process skills. With STEM-based e-modules integrated with reading materials and experimental activities, science learning can develop better and quality questioning skills (Nurramadhani et al., 2020).

This electronic module can be made using a flip book maker. Some of the advantages include; 1) animations and graphics are consistent and flexible for any window size and screen resolution on the user's monitor; 2) image quality is maintained; 3) program loading time is relatively fast; 4) the resulting program is interactive; 5) easy to create animation and 6) easy to integrate with several other programs (Maizora, 2016). The display of text, images, animation, and sound can be designed as creatively as possible with Macromedia flash to display the material or concept more attractively (Citrasukmawati et al., 2017). The courses on visualistic phenomena can be easily explained through several software advantages. One of the subjects that can be explained through visual animation is the wave vibration course.

Vibration and waves courses are compulsory subjects for undergraduate physics education study program undergraduate students. The material discussed includes vibrations ranging from simple harmonic motion to electromagnetic waves and advanced materials in basic physics 1. The learning outcomes of this course are a collection of concepts and their logical application in physics concepts and their applications. Critical. In addition to understanding theoretical concepts, students can also verify various concepts of vibration and waves through experimental activities in the laboratory. At the end of the lecture, students produce engineering products from the application of vibration and wave concepts.

From the results of interviews with lecturers in charge of vibration and wave courses, information was obtained that wave vibration training is carried out so that students master various concepts of vibration and waves as well as skills in verifying vibration and wave concepts through practical activities. However, students have not been directed to produce engineering products by applying vibration and wave concepts. So that the level of cognitive taxonomy of creating, which is the highest and most complex level (Gunawan & Paluti, 2017) in this course, has not been limited. The ability to create it with the ability to generalize and produce. The ability to generalize is the ability to think divergently, which is the core of creative thinking. The ability to handle a comprehensive dimension of knowledge involves not only one particular field of science but also other fields. This knowledge includes factual, conceptual, procedural, and metacognitive knowledge (Anderson & Krathwohl, 2002). Therefore, other learning approaches are needed to train students to produce engineering products by being associated with various factual and procedural knowledge, one of which is the science, technology, engineering, and mathematical (STEM) approach.

The STEM approach to learning is an innovation in education to develop the skills prospective physics teacher students need in the 21st century. Fitriyani et al. (2020) states that STEM education means involving four disciplines, namely science (IPA), technology (technology), engineering (Engineering), and mathematics (Mathematics). This is because of natural science, technology, engineering/engineering, and the basic foundation in the development of Science and Technology (IPTEK). The STEM approach can train students to solve real-world problems through a problem-solving-based design used by scientists.

Vibration and wave learning through STEM-based e-modules is the solution to help prospective physics teacher students develop their thinking skills. Students are expected to be successful in problem-solving to design a product like a scientist. This is shown from the results of expert research, and it is known that STEM learning can develop students' thinking skills. Research Fitriyani et al. (2020), concluded that higher-order thinking skills improve through STEM-based learning. Handayani et al. (2021) stated that the STEM integrated physical E-Module equipped with quizzes can train students' critical thinking skills. Therefore, in this study, we developed an interactive electronic lecture module based on the science, technology, engineering, and mathematics (STEM) approach in vibration and wave courses so that students can learn independently and their ability to produce a product can be expected. This research will focus on the development aspect so that electronic module products will be produced that meet the criteria for the validity and effectiveness of the media produced.

Methods

The method used in this study is a research and development method with a 4-D development model. The 4D development stage consists of 4 stages: Define, Design, Develop, and Disseminate (Sugiyono, 2018). The development chart for the STEM-based vibration and wave module is presented in Figure 1.

The define stage contains activities to implement what products will be developed and their specifications. This stage is a needs analysis activity carried out through research. Design (planning) contains activities to make designs for products that have been determined. Developing (development) contains activities to make a design into a product and repeatedly test the product's validity until the resulting product is valid, practical, and effective. Disseminate (dissemination) contains activities to disseminate products that have been tested for use by others.

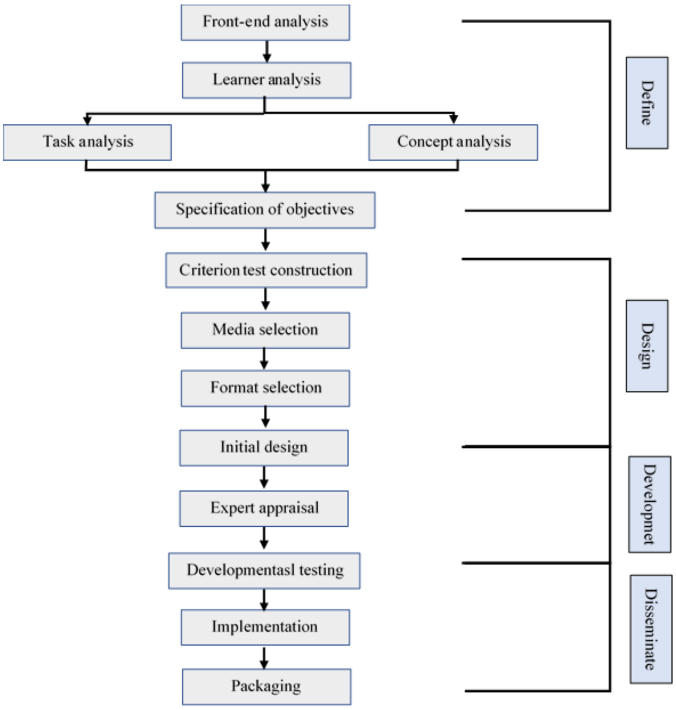


Figure 1. STEM-based vibration and wave module development chart

The research sample includes all physics education students taking vibration and waves courses. The data collected in the research are qualitative and quantitative. Data collection instruments used validation sheets, closing activities with a Likert scale, and essay tests to measure HOTS. The module aspect is seen from the material and media aspects. The material aspects include content, presentation, language, and STEM component approach. Media aspects include graphics or display, transitions, transition systems, animation systems, and evaluation systems in electronic modules. Meanwhile, the practicality level module developed was seen from student response questionnaires. Indicators of practicality aspects include (1) ease of accessing e-module links online, (2) ease of use of navigation features, (3) security from bugs (errors) in the application, (4) ease of self-study of e-modules, (5) access to e-modules to find time to find parts of the material, (6) ease of use of e-modules for daily learning, (7) the benefits of e-modules to stimulate learning motivation, (8) e-modules to improve understanding of material concepts, (9) the benefits of e-modules to increase interest in learning and (10) new knowledge presented in e-modules.

The quality of the module is seen from the height and practicality of the module. To view and apply the data analysis module using equations to determine the validity and practicality of the module (Sulastri et al., 2022). The results are interpreted in Tables 1 and 2. Meanwhile, for the module's effectiveness, effect size analysis was used (Cohen, 1998).

Table 1. Module Feasibility Interpretation Criteria

Interval	Criteria
$3.25 < V \leq 4.00$	Very valid
$2.50 < V \leq 3.25$	Valid
$1.75 < V \leq 2.50$	Less valid
$1.00 \geq V \leq 1.75$	Invalid

Table 2. Practical Interpretation Criteria for Modules

Interval	Criteria
P ≥ 85%	Very practical
70% ≤ P < 85%	Practical
50% ≤ P < 70%	Less practical
P < 50%	Inpractical

Results and Discussion

The development of e-modules based on the STEM approach using a 4D model includes define, design, develop and disseminate (Sugiyono, 2018). A needs analysis is carried out through document review and interviews at the defined stage. The documents reviewed include the Semester Implementation Plan (RPS), teaching materials, references, and practical guides for vibration and wave courses. Based on the results of the RPS study, it is known that the learning method applied in the vibration and wave courses generally uses the inquiry method. Students pose real problems in everyday life at the beginning of learning, and then students try to solve these problems. In addition, students are also given the freedom to formulate existing equations. Theories obtained in the classroom face to face are carried out through experiments in the laboratory. The learning media used in the course are laptops and blackboards. While the teaching materials used are handouts, reference books, and modules. The modules are prepared by a team of lecturers who are effective in the subject consisting of material, examples, and practice questions. Modules are made in printed form and have not been integrated with the inquiry method used in learning. The interviews with powerful lecturers showed that students had difficulty understanding the material. This can be seen from the exam results; most of the students solved the HOTS criteria. The lecturer said that when he trained students to inquire, the students seemed confused, so they needed extra guidance from the lecturer. Interviews with students also revealed that some of the materials on vibrations and waves were considered difficult by students. They say that many formulas are abstract in the matter of vibrations and waves. Therefore, it is necessary to develop STEM-based electronic modules to facilitate students in developing higher thinking skills, namely being able to analyze, develop and create. Handayani et al. (2021) found that STEM integrated physical e-modules can facilitate students in developing critical thinking skills to compete in the industrial revolution 4.0.

The design stage contains activities to design the product that has been determined. At this stage, the steps are carried out, namely: (1) formulating learning objectives and indicators, (2) determining learning materials and sub materials, (3) STEM components in each learning material, (4) preparing learning materials, (5) preparing structural modules, and (6) development of electronic modules using FlipBook Maker Pro. Learning objectives and indicators are based on sub-achievements of course graduates. The materials and sub-materials that will be discussed in the module are determined based on the objectives and indicators. The results of the STEM components for each material are presented in Table 3.

Table 3. Results of STEM Component Analysis on Vibration and Wave Materials

Materials	STEM Components			
	Science	Technology	Enginering	Mathematics
The Basic Concept of Harmonic Vibration	√	√	√	√
Superposition and Energy of Simple Harmonic Motion	√	√	√	√

Materials	STEM Components			
	Science	Technology	Enginering	Mathematics
Damped Vibration	√	√	√	√
Forced Vibration	√	√	√	√
Basic Concepts of Waves	√	√	√	√
Wave Properties	√	√		√
Mechanical Wave	√	√		√
Sound Wave	√	√	√	√
Electromagnetic wave	√	√	√	√

The structure of the module developed includes an introduction, a table of contents, an overview of the course, instructions for using the module, a presentation of material, and references. The material in the module is presented in 9 chapters, namely chapter 1, the basic concept of vibration, chapter 2, superposition and harmonic motion energy, damped vibration, chapter 4 vibration, chapter 5, basic wave concepts, chapter 6, wave properties, chapter 7, wave mechanics, chapter 8 sound waves, and chapter 9 electromagnetic waves. The material's preparation is based on the difficulty level and the material's order. The presentation of the material for each chapter consists of learning objectives, an explanation of the material accompanied by pictures, examples of questions and their solutions, practice questions, a let us explore column, a let us learn column and a summary.

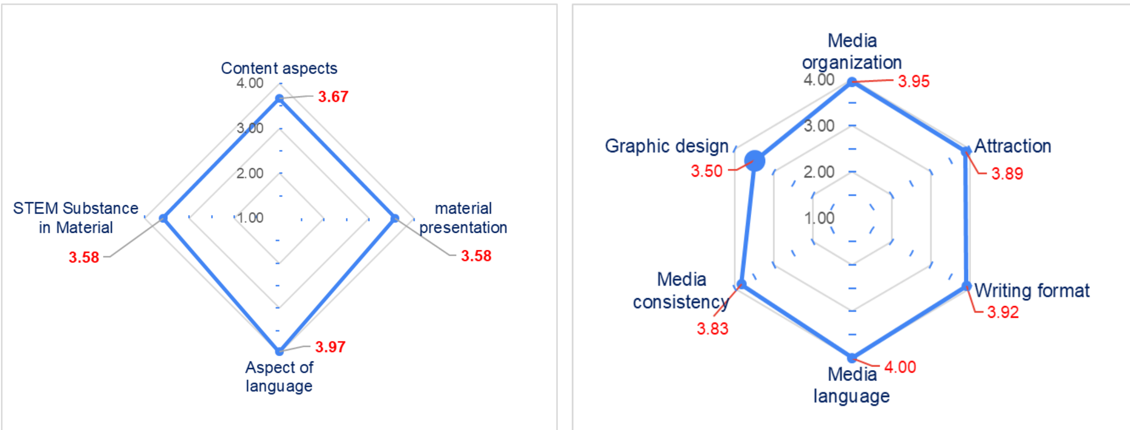


Figure 2. (a) Interpretation Result of Material Aspect Validation, (b) Interpretation Result of Media Aspect Validation

The developing stage contains activities to make a design to see the product and test its validity and practicality for the module validity and practicality. Validation was carried out involving three material experts and three media experts. The expert validates the module based on assessing the material and media aspects. The results become the basis for revising the e-module so that the STEM-based e-module is feasible to use. The results of experts' validation of material and media aspects show that the developed e-module has very valid criteria (Figure 2). The suggestions for module revision and improvement based on expert judgment are presented in Table 4 and Table 5.

Table 4. Revision of STEM-Based E-Module Design during the Material Expert Validation Process

Aspect	Expert assessment and revision suggestions	Revised results
Contents aspect	The material's depth is appropriate for achieving the learning objectives but has not fully provided a direct experience to students.	Material improvement is associated with phenomena in everyday life
Material Presentation	The material has been presented well but is not deep enough to start students exploring and innovating, and it is necessary according to the latest developments	Provide several stimuli and examples that are appropriate to the material and contextual so that students are interested in exploring and innovating
Aspect of language	The language used is easy to reach	-
STEM Substance in Material	STEM context packaging in daily activities, not in a practical setting. For example, a vehicle passes through a pothole in the road so that the motor shock "reacts."	In the let us explore section, a stimulus is given in the form of presenting phenomena in everyday life.

Table 5. Revision of STEM-Based E-Module Design during the Media Expert Validation Process

Aspect	Expert assessment and revision suggestions	Revised results
Module Organization	The module's structure is good enough; it should be arranged based on the material of the sequence, starting from basic to complex material	The material is presented from basic to complex and begins with real phenomena in everyday life
Attractiveness	The modules presented are quite interactive, and the work instructions are clear	The selection of images should be adjusted to the content of the material
Writing	The use type and size of letters are adjusted to be seen clearly when read using Android	Choose the appropriate font type and size so that it can be read clearly
Media Language	Already well	-
Media Consistency	Already well	-
Graphic design	The color combination is quite good but not yet contextual	Presenting contextual images

The practicality of STEM-based e-modules can be seen from the results of student responses to the use of e-modules. The questionnaire results have practical criteria with an average proportion of 76.75%. The results of the practicality of the e-module for each aspect are presented in Table 6.

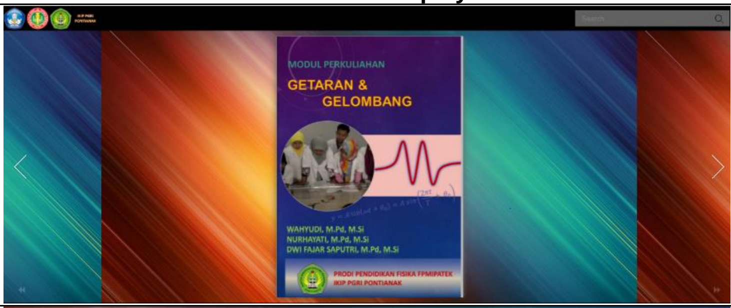
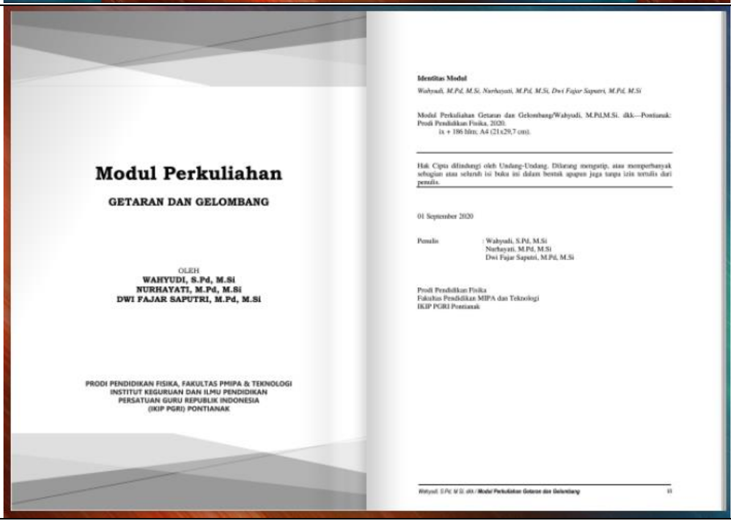
Table 6. Interpretation of E-Module Practicality

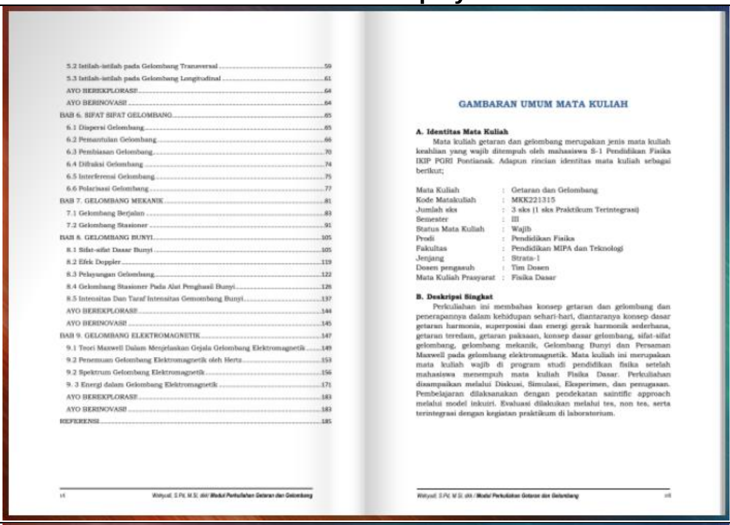
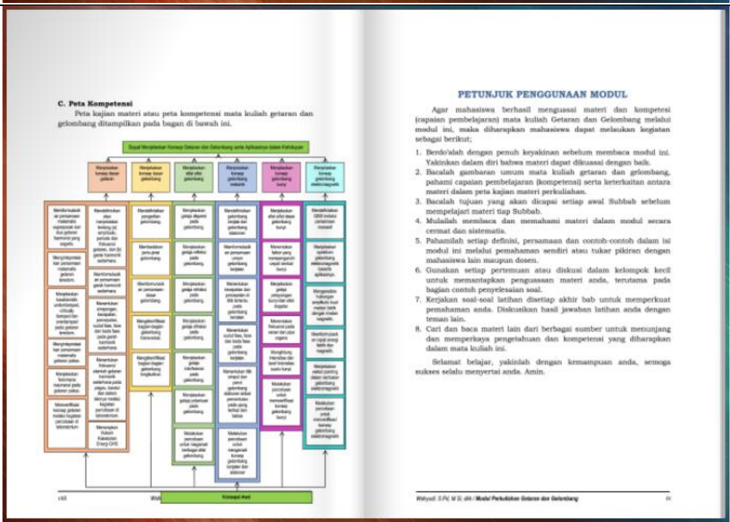
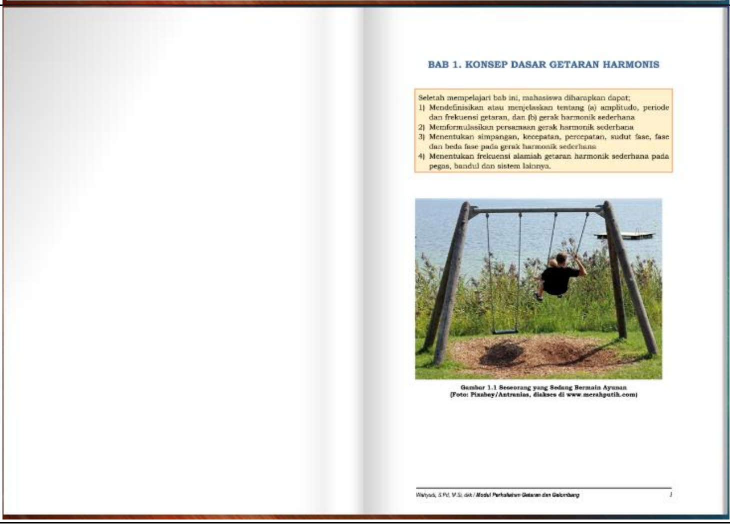
Aspects of Practical Assessment	Percentage (%)	Criteria
Ease of accessing e-Modul links online	80.00	Practical
Ease of use of navigation features	77.50	Practical
Security from bugs (errors) in apps	61.25	Less practical
E-Module ease of self-study	81.25	Practical
Access the e-module time finding parts of the material	71.25	Practical
Ease of use of e-modules for everyday learning	76.25	Practical
The benefits of e-modules are to stimulate learning motivation	81.25	Practical

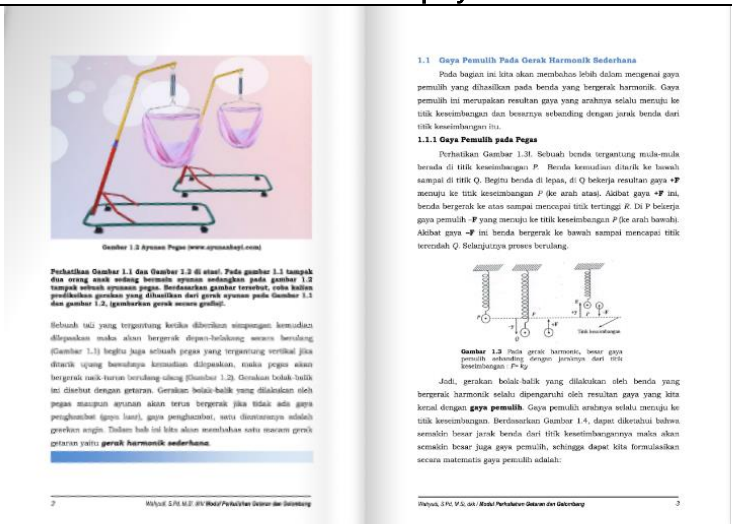
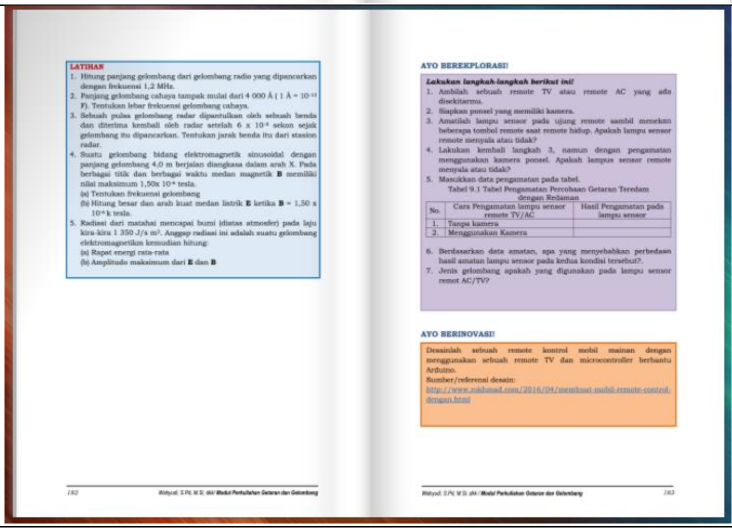
Aspects of Practical Assessment	Percentage (%)	Criteria
Benefits of e-modules to improve understanding of material	76.25	Practical
The benefits of e-modules are to increase interest in learning	81.25	Practical
New knowledge presented in the e-module	81.25	Practical
Average Percentage	76.75	Practical

Based on the expert validation test and e-module practicality test, it is known that the developed STEM-based e-module is feasible to use with very valid and practical criteria. This is to the research of Handayani et al. (2021), Sudirman et al. (2018); and Alfiriani & Hutabri (2017) concluded that quality learning modules are feasible to use in learning. Some parts of the e-module need to be improved according to the revision suggestions from the experts (Table 4 and Table 5). The results of the e-module display after the revision are presented in Table 7.

Table 7 Display of E-Module Parts After Revision

No	E-Module Display	Information
1		Initial view when clicking the module link
2		Cover display in e-module

No	E-Module Display	Information
3		General view of the course
4		Display of e-module usage instructions
5		Display of material presented in e-modules

No	E-Module Display	Information
		
6		Display of activity experiments and innovations

The electronic module design based on the STEM approach that has been developed has met the characteristics of the module. Deafirmanda et al. (2017) stated that a good module has the characteristics of self-instruction, self-containers, stand-alone, and adaptive. The developed module can be said to be self-contained because its presentation includes all the required learning materials. This module has fulfilled the stand-alone characteristics because to study, it does not depend on other teaching materials/media or does not have to be used together with other teaching materials/media. In addition, the module also fulfills adaptive characteristics because it has adapted to the development of science and technology; it has also made it easier for users, according to the practical results shown in Table 6.

Implementing e-modules that have been tested on students is at the dissemination stage. The results of implementing STEM-based e-modules through the HOTS test are presented in Table 8.

Table 8. Increasing Student HOTS in Each Aspect After Implementation of STEM-Based E-Modules

Aspect	N-Gain	Criteria
Analyze	0.49	Moderate
Evaluate	0.13	low
Create	0.30	Moderate

The use of STEM-based e-modules on vibrations and waves has been proven to increase the HOTS of prospective physics teacher students in all aspects of HOTS (Table 9). Improved aspects of analyzing and creating in the medium category and improving aspects in the low category. This result was also found by research (Nurhayati et al., 2022) that STEM-based e-modules can increase student HOTS. The effectiveness of the e-module implementation shows that the STEM-based e-module is very effective in increasing student HOTS (Table 9). Fitriyani et al. (2020); Mustofa (2016) also showed that STEM-based learning could increase students' HOTS. However, when viewed from every aspect of HOTS, the effectiveness of e-modules is still less effective in improving development aspects. The ability to make something based on certain criteria and standards Nurhayati & Angraeni (2017) states that it can be done if students can plan and carry out problem-solving appropriately, understand the correct objectives, and provide the right reasons/evidence so that the written answers will answer the question in question. The STEM steps in the module have supported the development of students' higher-order thinking skills through observation, experimentation, and innovation. However, in the experimental process, students have not been fully given the freedom to design experiments to solve problems. In the module, guiding questions are still presented for problem-solving. This makes students follow the questions in the module to explore students' abilities in development.

Table 9. Effectiveness of Using STEM-Based E-Modules in increasing student HOTS

HOTS Aspek Aspect	*d*	Criteria
Analyze	1.72	*Very Big*
Evaluate	0.12	*Very Small*
Create	0.94	*Very Big*
Overall	0.93	*Very Big*

Conclusion

The Vibration and Wave E-Module has been successfully developed using the STEM approach. The media and materials expert team has provided several suggestions for improving the design and substance of the e-module. The validity index shows the e-module is in very valid criteria. The e-module that has been developed is considered practical so that it is easy to use. The results of the effectiveness test show that the use of STEM-based vibration and wave e-modules can be effective in training and improving student HOTS. However, it is necessary to further develop the "creating" aspect of HOTS through the integration of STEM projects in vibration and wave e-modules..

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