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Harmonizing STEM with Arts: Crafting an Innovative Physics Electronic Module on Vibration and Wave Concepts

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Abstract: Art provides a unique lens through which to explore scientific phenomena, allowing students to visualize complex ideas and express their understanding in imaginative ways. Moreover, the combination of STEM and art, which we call STEAM, encourages holistic learning experiences. This study aims to develop STEAM-based electronic modules for physics learning, focusing on the Vibrations and Waves concept, and to assess the feasibility and attractiveness of this developed electronic module. This research follows a research and development (R&D) approach, employing a 3D development model (Define, Design, and Develop). The study was conducted at MTsN 1 Bandar Lampung, involving eighth-grade students as research participants. The research object was a STEAM-based electronic module on Vibrations and Waves material. Validation results were obtained from both media and subject matter experts, with both categories indicating a very high level of validation, signifying that the electronic module successfully meets the criteria for development based on media and subject matter. Furthermore, the results from development trials involving teachers and students indicated that the electronic module was highly attractive. Consequently, this study concludes that the developed electronic module is highly feasible as teaching material and is very attractive to use by teachers and students.

Keywords: Electronic module, Vibration and waves, Development, STEAM

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INTRODUCTION

As time goes by and the development of the times, the use of technology is becoming more developed in the community to achieve learning goals (Afriani & Fitria, 2021). According to Iskariyana & Ningsih (2021), Indonesian students are the highest users of technology on the education side. The results show that about 40% of Indonesian students are computer users. Besides that, about 67% of students use mobile phones in class and 81% use technology more often to do schoolwork. Based on this characteristic, teachers should have a good strategy to embed technology in the learning process. It means that the student's rapid use of technology requires teachers to be more innovative in the learning process (Iskariyana & Ningsih, 2021)

To foster innovation in the learning process, teachers must embrace a mindset of continual growth and exploration. Rather than adhering solely to traditional methods, educators should be encouraged to experiment with new teaching strategies, technologies, and methodologies. By cultivating an environment that values creativity and experimentation, teachers can adapt their approaches to better suit the diverse needs and learning styles of their students. Embracing innovation allows educators to harness the power of emerging technologies (Oke & Fernandes, 2020), such as interactive simulations, online collaborative platforms or teaching materials (Gan, Menkhoff, & Smith, 2015), and virtual reality experiences, to enhance engagement and deepen understanding. Moreover, fostering a culture of innovation in education not only benefits students by making learning more dynamic and relevant but also empowers teachers to evolve as professionals, continuously refining their craft to meet the evolving demands of the modern world.

The importance of instructional resources in the educational process cannot be overstated, as they serve as the foundation upon which knowledge is built and understanding is cultivated (Elenzi, 2020). Thoughtfully curated materials provide students with access to diverse perspectives, essential concepts, and real-world applications, thereby enriching their learning experiences. Well-designed materials can captivate students' interest, spark curiosity, and foster active engagement, creating an environment conducive to deeper comprehension and retention of information (Pluck & Johnson, 2011). Moreover, teaching materials play a crucial role in accommodating various learning styles and preferences, allowing educators to tailor their instruction to meet the diverse needs of their students. Whether it be textbooks, multimedia resources, hands-on activities, or digital tools, effective teaching materials empower both teachers and learners alike (Ertmer & Ottenbreit-Leftwich, 2010), facilitating meaningful interactions and facilitating the journey towards academic success. Ultimately, the careful selection and utilization of teaching materials are fundamental to cultivating an enriching and effective learning environment that nurtures intellectual growth and lifelong learning skills (Mouros, 2003).

An instructional resource with significant potential for capturing students' interest is an electronic learning module, commonly referred to as an electronic module. With the rapid advancement of technology, electronic modules offer a dynamic and interactive approach to learning that resonates with today's digitally savvy students. These modules can incorporate multimedia elements such as videos, animations, interactive quizzes, and simulations, creating a stimulating and immersive learning experience (Highsmith, 2021). By leveraging the flexibility of digital platforms,

electronic modules can cater to diverse learning styles and preferences, allowing students to engage with content at their own pace and in ways that resonate with them. Furthermore, the interactive nature of electronic modules encourages active participation and exploration, fostering deeper understanding and retention of concepts. Additionally, electronic modules can be easily updated and customized to reflect the latest developments in a subject area, ensuring that the learning materials remain relevant and up-to-date. Overall, the development of electronic modules represents a powerful opportunity to enhance student engagement and promote meaningful learning experiences in the digital age (Raharjo, Haqq, & Larasari, 2023).

Integrating the STEAM (Science, Technology, Engineering, Arts, and Mathematics) approach into electronic modules presents an innovative and holistic approach to education. Electronic modules can offer dynamic and interdisciplinary learning experiences that foster creativity, critical thinking, and problem-solving skills by blending them with STEAM (Erwin, 2017). Science and technology components can introduce students to foundational concepts and cutting-edge innovations, while engineering principles encourage design thinking and hands-on experimentation. The inclusion of art elements adds a creative dimension, encouraging students to explore connections between STEM concepts and artistic expression, and fostering innovation and ingenuity. Furthermore, mathematics serves as the backbone, providing the framework for logical reasoning and quantitative analysis throughout the learning process. By embracing the STEAM approach within electronic modules, educators can provide students with comprehensive and immersive learning experiences that prepare them to thrive in an increasingly complex and interconnected world (Erwin, 2017; Soroko et al, 2020). Through collaborative projects, interactive simulations, and real-world applications, STEAM-based electronic modules empower students to develop the skills and mindset necessary to tackle the challenges of the future with confidence and creativity (Erwin, 2017).

The study of STEAM-based physics and STEAM-based physics electronic modules in the past decade remains very limited, especially in physics education. For example, in 2023, there is STEAM project-based learning approach to enhance the teaching-learning process in the topic of Pascal's principle (Baidal-Bustamante et al., 2023), STEAM technology as a tool for developing creativity to identify problems of weakening of natural-technical and engineering components in secondary school (Раманкулов, Ш., Чорух, А., & Полатулы, 2022), teaching the concept of time: A steam-based program on computational thinking in science education (Bati et al., 2018), effectiveness of STEAM-based teaching materials to improve student's creative thinking skills (Sakinah & Widodo, 2019).

To harmonise STEM with arts (STEM) and because of the limitations of studying STEAM in physics, it is important to develop an STEAM-based physics electronic module. Besides that, there are research findings indicating that there is a misconception among junior high school students regarding the concept of waves and vibrations (Haerunnisa et al., 2022) indicating the necessity of a new method to address this issue. Therefore, it is important to develop STEAM-Based Physics Electronic Module Development on Vibration and Wave concept.

METHOD

This research is a type of research and development (R&D) following the development model referred to as 3D (Define, Design, Develop) by Thiagarajan and Semmel (1974). This research was only conducted up to the development stage as the researcher did not aim to assess the effectiveness of the developed product. The steps are described in Figure 1.

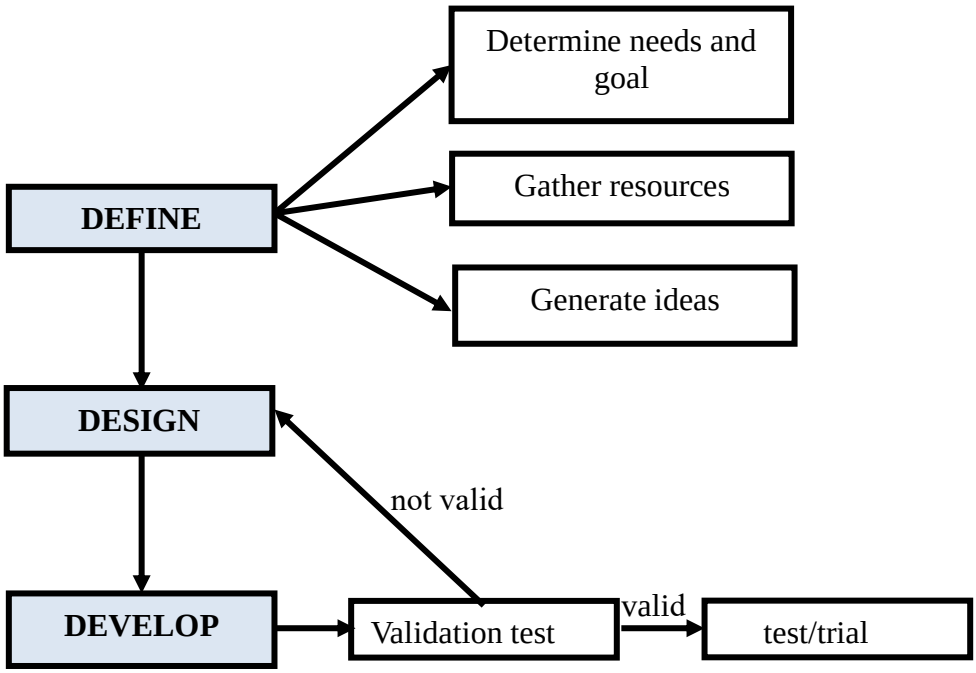


Figure 1. Development stages

Research Design & Procedures

The details of the development stages are as follows:

a) Define

The define stage contains activities to define the problem and the conditions needed for learning development. This stage becomes the most important initial stage before developing learning strategies. This stage consists of five activities, including:

1. Determine needs and goals
   In this part, we should determine the need and goal involves identifying the specific requirements and objectives of the project or becoming an initiative. This phase becomes the foundation for the entire development process and is crucial for ensuring that the product developed effectively addresses the intended needs and goals.
2. Gather resources
   Gathering resources involves acquiring the necessary materials, tools, expertise, and support needed to execute the project effectively. This part becomes critical

for ensuring that the project has access to the resources required to implement the defined goals and objectives successfully.

3. Generate ideas
   Generating ideas involves brainstorming and ideation to find potential solutions to address the identified needs and goals of the project. This part becomes crucial for stimulating creativity, generating diverse perspectives, and laying the groundwork for the development of effective solutions.

b) Design
   The stage of design is essential for translating conceptual ideas and requirements into a well-defined and user-centred design concept that serves as the blueprint for the development process. By focusing on user needs, functionality, and aesthetics, the Design phase lays the groundwork for the successful development and implementation of the project.

c) Develop
   In this part, the project takes shape and comes to life, as ideas are transformed into concrete solutions. The steps are careful planning, collaboration, and execution. This stage also involves expert validation and development trials (response of teacher and students).

Population and Sample

This research was conducted at MTsN 1 Bandar Lampung and the products developed were tested on 40 students.

Data Collection and Instrument

This study utilized an electronic module assessment instrument in the form of a material expert validation questionnaire and media expert validation beforehand. This was done to test the feasibility of the electronic module. Additionally, an assessment questionnaire was administered to students and educators to evaluate the attractiveness of the electronic module.

Data Analysis

The data and information gathered from the Likert scale measurement results are presented numerically. These numbers are then interpreted quantitatively. Table 1 describes the category of eligibility.

Table 1. Eligibility conversion score

No	Category	Score
1	Excellent	5
2	Very Good	4
3	Good	3
4	Enough	2
5	Not enough	1

The score obtained is then converted to determine the percentage of eligibility (e) using the following formula and after calculating the %, then interpret the data according to tables 2 and 3.

$$e(\%) = \frac{\text{The scores obtained}}{\text{The maximum scores}} \times 100\%$$

Table 1.Criterion Interpretation Scaleof media and material experts

Intervals	Criteria
0% - 20%	Very Low
21% - 40%	Low
41% - 60%	Moderate
61% - 80%	High
81% - 100%	Very High

Table 2. Criterion Interpretation Scale of the response of teachers and students

Intervals	Criteria
0% - 20%	Very Unattractive
21% - 40%	Not attractive
41% - 60%	Quite attractive
61% - 80%	Attractive
81% - 100%	Vey attractive

RESULT AND DISCUSSION

Define

At this stage, it was found that MTsN 1 Bandar Lampung uses the 2013 curriculum in the teaching and learning process. Then the characteristics of students who belong Z generation and the Alpha generation which born in the digital age they are highly proficient in navigating various digital platforms and technologies, often multitasking across different screens simultaneously. Almost all of the students have their handphones and can operate computers. Another fact shows that teachers typically lead classroom activities, deliver lectures, and provide direct instruction, while students listen, take notes, and complete assignments. This of course gives students limited space to express their thoughts and opinions

The distinct characteristics of Generation Z and Alpha Generation make them highly suitable candidates for the development of electronic modules. With their innate digital fluency and proficiency in navigating various online platforms, Generation Z students are well-equipped to engage with interactive and multimedia-rich content delivered through electronic modules.

After identifying the specific requirements of this study, we find out the student's difficulty in the learning process, especially physics. It can be found that there is still the lowest score of physics material in learning vibration and wave concepts.

Then, we identify the basic competence of this concept (Table 4) before developing an electronic module. So that the learning media that will be developed relates to Basic Compeltelncy and Compeltelncy Achielvelmelnt Indicators.

Table 3. Basic Competency and Competency Achievement Indicators

Basic competencies	Indicators of Competence Achievement
3.11 Analyzing the concepts of vibration, waves, and sound in everyday life including the human auditory system and the sonar system in animals	3.11.1 Observing the phenomena of vibrations on pendulum swings, waves on ropes/slinky and sounds from various sound sources. 3.11.2 Observing the hearing mechanism in humans and the sonar system in animals 3.11.3 Identify the parts of the auditory system to determine the mechanism of hearing in humans.
4.11 Preliminary experimental results about vibration, waves, and sound.	4.11.1 Conduct an experiment to measure the period and frequency of a pendulum swing. 4.11.2 Experiment to measure the magnitudes of the waves 4.11.3 Conduct sound frequency and resonance experiments to explain sonar systems in animals. 4.11.4 Presenting the results of the experiment and identification in the form of a written report and discussing it with friends.

Based on the problems found, By integrating art into education, teachers can tap into the innate creativity of Z and alpha-generation students, fostering a deeper understanding and appreciation of diverse subjects and concepts. Whether through visual arts, music, theatre, or digital media, art offers Z and Alpha Generation students opportunities for self-discovery, collaboration, and innovation in the learning process. Additionally, the interplay between art and technology opens up new possibilities for creative expression and interdisciplinary learning, preparing students for success in a rapidly evolving and interconnected world where creativity and adaptability are highly valued. Therefore, we provide an alternative way to overcome this problem by improving existing teaching materials using STEAM-based learning models. This STEAM-based learning el-module provides convenience for students because teaching materials to be developed can be accessed using smartphones or PCs. In addition, in the developed e-module there are pictures, animations, and learning videos that make it easier for students to understand the material presented.

Design

The learning media developed by researchers is in the form of STElAM-based el-modules on Vibrations and Waves. Figure 2 shows el-modules developed with several STElAM-based el-module design selections.

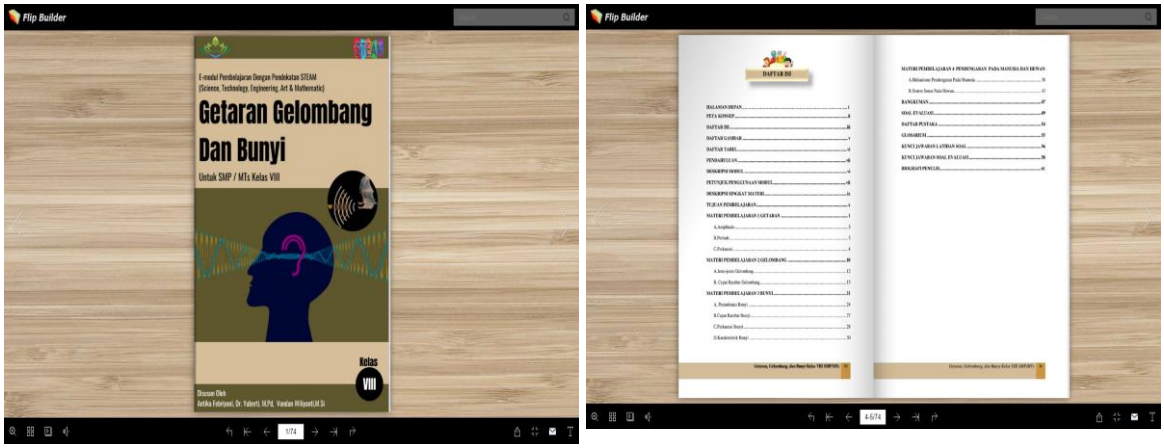


Figure 1.Front view of STEAM-based e-modules

Development

In this stage, the development and expert validation will be carried out and become crucial for ensuring the effectiveness and reliability of the proposed solution or intervention. During this stage, the conceptualized ideas and designs are translated into tangible products or prototypes through iterative cycles of refinement and testing. This iterative process allows for feedback from various stakeholders, including subject matter and media experts (validation), educators, and end-users (students), to be incorporated into the development process, ensuring that the final product meets the intended objectives and addresses the identified needs. While specific content of the final product that has been developed is shown in Figure 3.

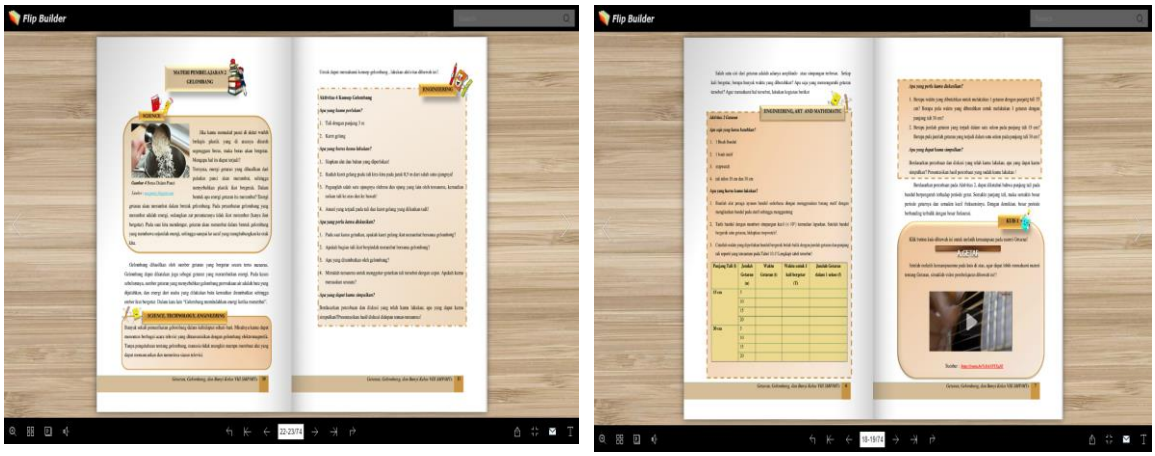


Figure 3. Content that integrates science, technology, Engineering (left) and Engineering, Art and Mathematics, and quizzes and learning videos (right)

Table 4. Media Expert Validation Results

No	Aspect	Percentage (%)	Criteria
1	Visual Display	84.44	Very high
2	E-Module Design	83.33	Very high
3	Ease of Use	83.33	Very high
	Aspect Average	**83.7**	**Very High**

Table 5. Material Expert Validation Results

No	Aspect	Percentage (%)	Criteria
1	Content Eligibility	84.16	Very high
2	Eligibility of Presentation	82.22	Very high
3	Language Eligibility	93.33	Very high
	Aspect average	**86.57**	**Very High**

The STEAM-based el-module that was developed was evaluated by 3 media experts and 3 subject matter experts using a questionnaire validation sheet. The result of this validation can be seen in Tables 5 and 6. Based on Table 5, the average score from media experts is 83.7 (very high). It means that the electronic module developed is very feasible to use based on the media developed. Some suggestions and improvements from the validator such as selecting and adjusting the thermal colour, adding the UIN and STEAM logos, adjusting the image to the material on the front cover, adding a cover design in the el-module, adding an author biography and a brief description of the el-module as the back cover, adding columns quizzes and learning videos, improved concept maps, added a list of images and a list of tables. In addition, the results of the material validation carried out by 3 validators generally obtained a percentage value of 86.57% (very high). It means that the el-module is very feasible to use based on content material. Some suggestions and input from material experts such as selecting and adjusting one of the three simple pendulum images and explanation of images of vibration material, adding wave illustrations and brief explanations of images on the material, adding images or illustrations of each type of wave, using aquation in each equation, elaborating the equation examples of wave propagation questions, and adding source links to each image.

After the stage of validation, the developed e-module then is tested to students and educators to assess its attractiveness. The results of responses related to the e-module obtained from students and subject teachers are written in the table 7. Based on Table 7, we can conclude that both learners (teachers) and student's responses, to the electronic module developed are very attractive. In addition, students gave positive responses to the el-modules that were developed, including this el-module which is an excellent learning media with quizzes, learning videos, and practical questions which are accompanied by answer keys making it easier for students to study independently.

Table 6. Student and Educator Response Results

Respondents	Average score (%)	Category
Learners	88.00	Very attractive
Educator	82.00	Very attractive

Discussion

Integrating art into the electronic module of physics offers a dynamic approach to harmonizing STEM disciplines with creative expression. By incorporating elements of art into the learning process, students are not only exposed to the scientific principles of physics but also encouraged to explore their creativity and imagination. Moreover, artistic activities such as drawing scientific diagrams or embedding simple musical instruments in the learning process provide students with opportunities to deepen their understanding of complex concepts while fostering their artistic skills. This harmonises STEM with art then we call "STEAM". In this study, we have been developing STEAM-based physics electronic modules on the Vibrations and Waves concept based on the 3D Model stage, define, design, and development.

This electronic module consisted of 5 components of STEAM, which are Science, Technology, Engineering, Art, and Mathematics in each part of the page. Science fosters curiosity and critical thinking, enabling students to explore the natural world and understand its phenomena through observation and experimentation. Technology empowers students to harness innovation and creativity, providing tools to solve real-world problems and enhance efficiency in various domains. Engineering encourages students to apply scientific principles and technological advancements to design and construct solutions, fostering problem-solving skills and ingenuity. Arts stimulate imagination and self-expression, allowing students to communicate ideas and emotions through various mediums such as visual arts, music, and performance. Mathematics provides the language and framework for understanding patterns, relationships, and structures, supporting logical reasoning and quantitative analysis across diverse fields. Each component is shown in Figure 4-7.

Based on Figure 4, this part belongs to the science component. This section contains knowledge about abilities and concepts that apply in nature. Students are stimulated by the activity of strumming a guitar and the vibrations that occur when pouring rice into a container. This stimulation is arranged to make students able to correlate the material to be studied with phenomena that they often experience.

Figure 4. Science Activity

Based on Figure 5, Graphic illustrations depicting human innovations in modifying the environment to meet human needs are presented. These illustrations aim to facilitate students' understanding of how humans have altered the environment. Additionally, students are encouraged to revisit the concept of vibration.

Jika kamu pernah berada di stasiun kereta api, ketika kereta api datang atau lewat kamu akan merasakan tanah yang kamu injak terasa bergetar. Getaran juga terjadi pada kaca-kaca jendela rumah ketika terjadi guntur yang kuat. Bunyi yang disebabkan guntur tersebut mampu menggetarkan benda-benda seperti kaca jendela. Bahkan getaran sangat kuat yang terjadi dari ledakan sebuah bom mampu merobohkan gedung-gedung.

Gambar 2 Kereta Api

Sumber : https://ucuk-mireia.blogspot.com

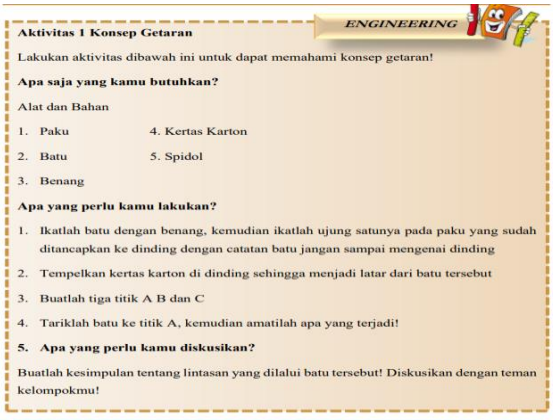
Semua benda akan bergetar apabila diberi gangguan. Benda yang bergetar ada yang dapat terlihat secara kasat mata karena simpangan yang diberikan besar, ada pula yang tidak dapat dilihat karena simpangannya kecil. Benda dapat dikatakan bergetar jika benda bergerak bolak-balik secara teratur melalui titik kesetimbangan.

Tes Kemampuan

Sebelum memahami lebih jauh materi Getaran, kerjakan kuis dibawah ini untuk menguji kemampuan awal! Klik button dibawah ini untuk mulai mengerjakan kuis.

Figure 5. Component of Technology

In the section of engineering, students are encouraged to cultivate the skills needed to design procedures for problem-solving. They have to design activities utilizing the provided tools and materials to gain a deeper understanding of the concepts of vibrations and waves.



ENGINEERING

Aktivitas 1 Konsep Getaran

Lakukan aktivitas dibawah ini untuk dapat memahami konsep getaran!

Apa saja yang kamu butuhkan?

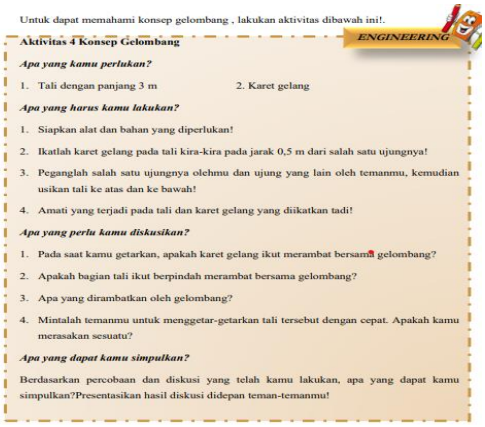
Alat dan Bahan

1. Paku
2. Batu
3. Benang
4. Kertas Karton
5. Spidol

Apa yang perlu kamu lakukan?

1. Ikatlah batu dengan benang, kemudian ikatlah ujung satunya pada paku yang sudah ditancapkan ke dinding dengan catatan batu jangan sampai mengenai dinding
2. Tempelkan kertas karton di dinding sehingga menjadi latar dari batu tersebut
3. Buatlah tiga titik A B dan C
4. Tariklah batu ke titik A, kemudian amatilah apa yang terjadi!
5. **Apa yang perlu kamu diskusikan?**

Buatlah kesimpulan tentang lintasan yang dilalui batu tersebut! Diskusikan dengan teman kelompokmu!



Untuk dapat memahami konsep gelombang , lakukan aktivitas dibawah ini!.

ENGINEERING

Aktivitas 4 Konsep Gelombang

Apa yang kamu perlukan?

1. Tali dengan panjang 3 m
2. Karet gelang

Apa yang harus kamu lakukan?

1. Siapkan alat dan bahan yang diperlukan!
2. Ikatlah karet gelang pada tali kira-kira pada jarak 0,5 m dari salah satu ujungnya!
3. Peganglah salah satu ujungnya olehmu dan ujung yang lain oleh temanmu, kemudian usikan tali ke atas dan ke bawah!
4. Amati yang terjadi pada tali dan karet gelang yang diikatkan tadi!

Apa yang perlu kamu diskusikan?

1. Pada saat kamu getarkan, apakah karet gelang ikut merambat bersama gelombang?
2. Apakah bagian tali ikut berpindah merambat bersama gelombang?
3. Apa yang dirambatkan oleh gelombang?
4. Mintalah temanmu untuk menggetar-getarkan tali tersebut dengan cepat. Apakah kamu merasakan sesuatu?

Apa yang dapat kamu simpulkan?

Berdasarkan percobaan dan diskusi yang telah kamu lakukan, apa yang dapat kamu simpulkan?Presentasikan hasil diskusi didepan teman-temanmu!

Figure 6. Component of Engineering

Based on Figure 7, in this development, it can be known that the art component does not stand alone but combines with science. In this section, student students are asked to watch videos showcasing various musical instruments through the links

provided in the electronic module. This is intended to offer students insight into the concept of vibrations, which generate rhythmic sounds.

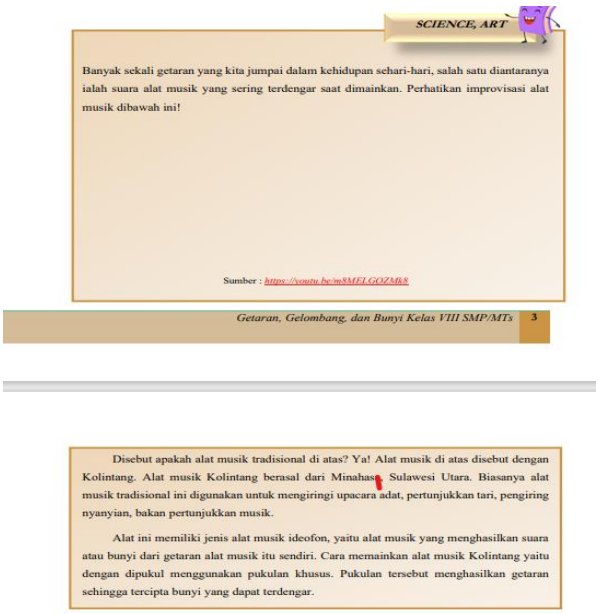


Figure 7. Science and Art

Figure 8 shows us the formulation of period and frequency. These physical quantities are provided to enable students to discern the relationship between quantities in vibrations and waves. However, mathematics can also be seamlessly integrated into science, technology, engineering, and art. Likewise, each component can be interrelated with one another.

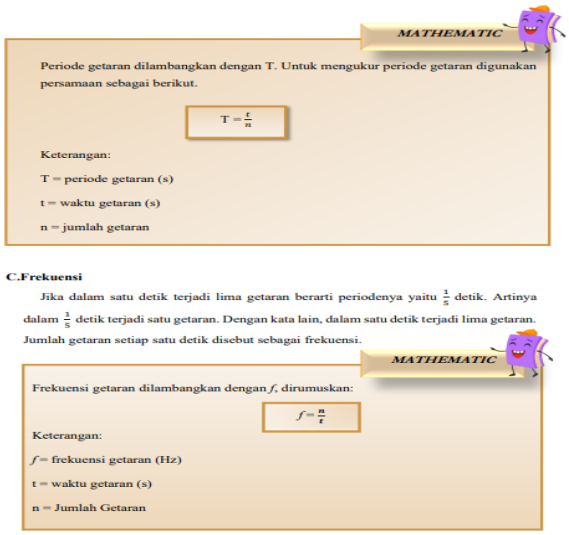


Figure 8. Mathematic component

The developed STEAM-based physics learning electronic modules on the Vibrations and Waves concept hold immense appeal, particularly for both students and educators, due to several compelling reasons. Firstly, by integrating science, technology, engineering, arts, and mathematics, these modules offer diverse perspectives and foster holistic understanding, preparing students for the complexities of the modern world. Besides that, STEAM electronic modules provide an innovative and interactive learning experience that engages students in multidisciplinary exploration (every single step of the component). Additionally, STEAM electronic modules also promote creativity and critical thinking by encouraging hands-on experimentation, problem-solving, and collaborative projects. They empower students to apply theoretical concepts to real-world scenarios, enhancing their practical skills and innovative capabilities (Erwin, 2017). Furthermore, for educators, STEAM electronic modules offer a versatile and customizable teaching tool that accommodates diverse learning styles and preferences (El Bachari & El Adnani, 2011). With access to multimedia resources, simulations, and interactive activities, educators can create dynamic and personalized learning experiences tailored to the needs and interests of their students (Liu, 2003). Overall, the development of STEAM electronic modules presents an exciting opportunity to revolutionize education, providing both students and educators with the tools and resources needed to thrive in the 21st century.

CONCLUSION

Based on the data and analysis of the development of the STEAM-based physics learning electronic module on Vibrations and Waves, it can be inferred that the developed module has achieved remarkably high scores in both media and subject matter validation. This indicates that the electronic module has successfully met the criteria for development based on media and subject matter. Moreover, both teachers and students have responded positively (very attractive) to the developed module. However, this electronic module still lacks detailed indicators focusing on the skills that students will develop. Additionally, it is necessary to conduct trials on a larger scale so that this electronic module can be developed on a larger scale.

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