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Validity of Smart E-Book Learning Media with a STEM Approach on the Topic of Vibration, Waves, and Their Application in Junior High School Science

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Abstract

21st-century learning emphasizes the importance of integrating technology in teaching and learning process. One of the innovations that has the potential to support the achievement of 21st-century competencies is the use of creative and interactive learning media. Integrating technologies such as Artificial Intelligence (AI) and Augmented Reality (AR) is considered effective in helping students understand abstract concepts, because they can present interactive visualizations and contextual learning experiences. This study aims to analyze the validity of Smart E-book learning media with a STEM approach on the topic of vibration, waves, and the use of junior high school. This research uses the Research and Development (R&D) method with a 4-D development model by Thiagarajan, which consists of four stages: define, design, develop, and disseminate. The assessment of the media validity test involved media experts and material experts, five validators each. The data collection instrument is in the form of a validation sheet, which includes media operational aspects, presentation, completeness, material accuracy, and material integration, and is then tested for readability by students. The media experts' assessment reached 99.6% and the material experts reached 98%, both were categorised as "very valid", and the average readability score of 93,33% was calculated from the three aspects: material, media, and media usage. Thus, Smart E-book learning media with a STEM approach have high validity, and can be accepted as a learning product that is accurate, relevant, in accordance with curriculum needs, and has the potential to be the basis for future research to be used at the trial stage in the classroom.

How to Cite

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INTRODUCTION

The 21st-century learning system is a previous educational regulation that was developed to emphasize the center of the learning process in students, where previously educators were the main center. So that learning is designed to be interactive, challenging, inspiring, fun, and motivates students to actively play a role in every activity based on national education standards (Permendikbud No.57, 2021). Thus 21st-century education emphasizes the need for learners to become individuals who have innovation, creativity, intelligence, global competence, and thinking and learning skills (Muldagaliyeva, 2023). Required skills include problem-solving, critical thinking, collaboration, and communication. All of these skills are expected to be possessed by learners when educators successfully develop a lesson plan that includes activities that challenge them to think critically in problem-solving. Activities that encourage collaboration and communication between students should be reflected in every lesson plan created by educators (Rasyad & Wulandari, 2024). Student-centered learning is different from educator-centered learning, the character of learning in the 21st century includes Communication, Collaboration, Critical Thinking, and Problem Solving, as well as Creativity and Innovation or often called the 4Cs in 21st century education.

The independent curriculum emphasizes the need for students to master the concepts taught as part of achieving learning outcomes (Viola & Kurniati, 2025). The ability of students to understand concepts is essential in the science learning process. The ability to understand concepts is one of the important indicators for achieving success in science learning. One problem in science learning is low conceptual understanding (Yulisa et al., 2020). In fact, when given a concept comprehension test, most students cannot complete it, and only a few answer with correct steps and answers. Some of the mistakes made by students in answering questions include errors in concepts, facts, procedures, and principles (Hutagalung, 2017).

Conceptual understanding is a person's ability to understand a concept. Students are said to understand a concept if they have grasped the meaning or significance of a concept and can explain something using their own words and apply it in their daily lives. Therefore, it is considered a key indicator of successful learning because it reflects the depth of knowledge students acquire (Pratiwi et al., 2022). A higher level of knowledge acquired is conceptual understanding, so mastery or knowledge is needed to understand (Aen & Kuswendi, 2020). This means that students can understand a concept based on their study subjects. In agreement with this, Dewi & Ibrahim (2019) state that students' conceptual understanding ability is the ability to master the learning material obtained through memorization and express material obtained with an understanding.

Many students say that physics is hard to understand because it focuses heavily on formulas, which makes them reluctant to listen or pay attention. Due to this stereotype, students often struggle to grasp the material. One example is the topic of Vibrations, Waves, and Their Applications. Sometimes students understand the concepts but find it challenging to apply them to problem-solving, while others rely on memorizing formulas without understanding the underlying principles (Suyatna, 2019). The topic of vibrations, waves, and their applications involves understanding the relationships between frequency, period, amplitude, and the energy contained in vibrations or waves. Vibrations are periodic back-and-forth movements, while waves propagate the energy generated by these vibrations (Rismawan & Aisiyah, 2023). This concept includes the types of waves (transverse and longitudinal), their properties, and their applications in everyday life, such as in communication technology, sonar, and medicine (Anggelia et al., 2024). An improved understanding of this topic can be achieved through interactive and application-oriented learning approaches. For example, students can conduct simple experiments to observe wave properties using tools such as a Slinky, water, or resonators, and explore the use of waves in modern technology. In this way, students understand the theory and see the relevance of these concepts in real life, such as the use of sound waves in ultrasound examinations or the role of electromagnetic waves in wireless communication. Through simple experiments, computer simulations, varied teaching media, or group discussions, students can develop the ability to apply physics principles in real-world situations, thereby enhancing their problem-solving skills. The results of Christiani et al. (2021) indicate that many students still hold misconceptions about the concepts of vibration and waves. The most common misconception involves the concept of amplitude, where students often believe that amplitude is the distance traveled by a vibrating object as it moves back and forth through its equilibrium point (Hasanah et al., 2025). Scientifically, amplitude is defined as the maximum distance a vibrating object travels from its equilibrium position. Students consider

this material abstract and complex, which frequently leads to misunderstandings. Students also struggle with other sub-concepts, such as the relationships among frequency, period, and wavelength, as well as the applications of waves in everyday life. These findings underscore the importance of using more concrete teaching methods, such as experiments or interactive simulations, to help students develop a deeper understanding and reduce misconceptions.

Based on this need, students are considered to have conceptual understanding and problem-solving skills when they achieve satisfactory learning outcomes, both in terms of conceptual knowledge and the ability to apply concepts in real-world situations. Therefore, effective learning media is necessary to foster students' conceptual understanding and problem-solving. Learning media serves as a tool to help teachers convey information, concepts, facts during learning process, using approaches that reinforce these skills.

One type of learning media that is particularly practical and engaging in the classroom is the interactive e-book. E-books can present material concepts alongside illustrations that clarify the content (Binti et al., 2024). According to Andaresta & Rachmadiarti (2021) learning through a STEM approach helps students apply the knowledge they acquire at school to real-world phenomena. Thus, integrating e-book learning media with a STEM approach is considered more effective: it makes learning more relevant for students, stimulates broader experiences, enhances conceptual understanding, and supports problem-solving skills (Iswahyudi et al., 2023). Integrating advanced technologies, such as Artificial Intelligence (AI) and Augmented Reality (AR), in interactive science e-books represents an innovative step to improve learning quality (Judijanto et al., 2025). AI is a virtual assistant capable of providing adaptive feedback, analyzing students' answer patterns, and recommending remedial or enrichment materials tailored to individual needs. Meanwhile, AR offers interactive 3D visualizations such as atomic structures, human organs, or wave simulations making abstract concepts more concrete. The combination of AI and AR makes learning more engaging and contextual and promotes critical thinking, digital literacy, and 21st-century problem-solving skills (Papanastasiou, 2019).

Valid learning media is required to effectively implement STEM-based learning regarding content, appearance, and usability. Media validity is a crucial initial benchmark before a medium is widely used in the classroom. Valid learning media is required to effectively implement STEM-based learning regarding content, appearance, and usability. Media validity is a crucial initial benchmark before a medium is widely used in the classroom. Content validity ensures that the material aligns with the curriculum, learning objectives, and student characteristics. Validity assessments typically involve experts in content, design, and pedagogy. However, many learning media are developed without a systematic and measurable validation process, which can result in a mismatch between the media, students' learning needs, and the intended learning approach. Therefore, developing STEM-based learning media must undergo a rigorous validation process to ensure appropriateness, suitability, and support for achieving 21st-century competencies. This study aims to examine the validity of the developed STEM-based Smart E-book learning media and evaluate the extent to which the media meets scientific, pedagogical, and technical criteria based on expert assessment.

METHOD

The primary focus of this research during the development stage was to produce valid and practical learning media refined based on expert input. Data were collected using a non-test method in the form of a questionnaire. The validation instrument consisted of 15 items addressing the media aspect operation, presentation, and completeness, and 13 items addressing material validation accuracy and integration of material.

This research was carried out over four months, from February to May 2025, with five junior high school science teachers from several schools in Semarang serving as media and material validators. The learning media, revised according to suggestions from media and material experts, were subsequently tested for readability in class IX A at SMP Negeri 40 Semarang.

Validation testing aims to measure the suitability of multimedia learning media. The validation procedure consisted of the following steps: 1) Meeting with experts to request their participation as validators. 2) Providing the media prototype to the validators for product assessment. 3) Distributing a validity questionnaire to media and subject-matter experts. 4) Revising the prototype based on the experts' feedback.

In addition to validation by experts, a readability test was also conducted involving 35 students as respondents. The readability test aimed to determine the extent to which the media was easy to understand, enjoyable, and practical for

use by students. At this stage, students were asked to try using the media directly, then provide an assessment through a readability questionnaire. Assessment aspects include: (1) material aspects, (2) media aspects, and (3) usage aspects.

The validation and readability data were analyzed using the following formula:

$P = \frac{f}{N} \; x \; 100\%$

P = percentage of points obtained
f = total points obtained
N = maximum possible points

The questionnaire assessment criteria are presented in Table 1.

Table 1. Validity Criteria

Percentage	Criteria
81.25%< P ≤100%	Highly Valid
62.50%< P ≤81.25%	Valid
43.75%< P ≤ 62.50%	Less Valid
25.00%< P ≤43.75%	Invalid

(Sudijono, 2008)

In terms of media readability, the criteria used are outlined in Table 2.

Table 2. Media Readability Criteria

Percentage	Criteria
81.25%< P ≤100%	Very Good
62.50%< P ≤81.25%	Good
43.75%< P ≤ 62.50%	Quite
25.00%< P ≤43.75%	Not Good

(Sugiyono, 2019)

RESULT AND DISCUSSION

The validity of the STEM-based Smart E-book was tested through an assessment conducted by five experts, consisting of media experts and subject-matter experts, namely teachers of integrated science. The selected teachers were required to meet several criteria: (1) an educational background of at least a bachelor's degree in science education or physics education, (2) a minimum of five years of teaching experience, (3) mastery of the applicable curriculum, and (4) prior involvement in the use or evaluation of learning media.

The purpose of the validation was to assess the suitability of the content and the appropriateness of the STEM-based Smart E-book before its implementation in the research trial. The media was considered valid if it obtained a score higher than 62.25% from both media and subject-matter experts (Arikunto, 2013). Media validation covered three aspects: operational features, presentation, and completeness. The assessment results indicated that all aspects received high scores, with averages ranging from 3.8 to 4.0 and validity percentages between 95% and 100%. Overall, the STEM-based Smart E-book was categorized as Highly Valid. Specifically, regarding operational aspects, all four indicators achieved the maximum score (4.0), corresponding to 100% validity, and were placed in the Highly Valid category. The detailed validation results from the five media experts are presented in Table 3.

Table 3. Media Validation Results by Media Experts

Validator	Percentage (%)	Interpretation
Expert 1	100	Highly Valid
Expert 2	100	Highly Valid
Expert 3	100	Highly Valid
Expert 4	100	Highly Valid
Expert 5	98	Highly Valid
Average	99.6	Highly Valid

Table 4. Validation Data for Each Aspect

No	Aspect assessed	Score	Criteria
Media Operations			
1	The STEM-based Smart E-book media helps students understand the material on Vibrations, Waves, and Their Applications in junior high school.	4	Valid
2	The visualization of the material presented in the Smart E-book helps facilitate students' understanding.	4	Valid
3	The Smart E-book is easy to maintain (1) does not require high costs, 2) does not require special maintenance, and 3) does not require experts.	4	Valid
4	Ease of use of the Smart E-book, 1) reusable, 2) highly practical, 3) lightweight/easy to open in the long term.	4	Valid

No	Aspect assessed	Score	Criteria
Media Presentation			
5	The readability of Smart E-books includes 1) font size, 2) font type, and 3) font color, which are used proportionally.	4	Valid
6	The color selection between components in Smart E-books is 1) contrasting, 2) proportional, and 3) attractive to students.	4	Valid
7	The placement and arrangement of components in the Smart E-book include 1) text, 2) images, and 3) videos that are neatly arranged, balanced, proportional, and appropriate.	3.8	Valid
8	Image presentation in the Smart E-book 1) high definition quality, 2) clear, and 3) includes image captions.	4	Valid
9	The presentation of videos in the Smart E-book is 1) high definition, 2) clear, and 3) easily accessible.	4	Valid
10	The links in the Smart E-book are 1) relevant to the material, 2) easily accessible, and 3) have valid sources.	4	Valid
Media Completeness			
11	Complete Smart E-book components include 1) title, 2) table of contents, 3) instructions for use, 4) general instructions, 5) STEM description, concept understanding description, 6) problem-solving skills description, 7) TP and CP, 8) material, 9) Quiz, 10) final assessment.	4	Valid
12	The cover includes 1) an appropriate title, 2) the name and institution of the developer, 3) aspects of integration.	4	Valid
13	The visualization of the content is consistent with the material on Vibrations, Waves, and Their Applications at the junior high school level.	4	Valid
14	Contains 1) interactive animations, 2) games and virtual experiments, 3) background music that is presented in an interesting manner, in line with the concept, and arranged appropriately in the Smart E-book.	4	Valid
15	The Smart E-book can 1) motivate students, 2) make students active, and 3) provide flexibility in learning.	4	Valid

The validation results obtained by five experts yielded the following validation scores: Expert 1 scored 100%, Expert 2 scored 100%, Expert 3 scored 100%, Expert 4 scored 100%, and Expert 5 scored 98%. All of these values fall within the "Highly Valid" category, indicating that each validator assessed the developed media as having a high level of accuracy and suitability concerning the aspects being assessed. The overall average percentage of 99.6% is also in the "Highly Valid" category, indicating that the innovative learning media product has met the criteria for content, appearance, language, and presentation in accordance with scientific principles and learning objectives. This aligns with Amelia (2019) opinion that good learning media must have a high level of operability, namely ease of use, maintenance, smooth navigation, and ability to function properly in various conditions. Ease of access and efficiency are essential so that students and teachers can focus on the material, not the technicalities of use. In terms of media presentation, six of the seven indicators received a perfect score.

In contrast, one indicator, Placement and arrangement of Smart E-book components, received a score of 3.8 (95%), but still fell into the "Highly Valid" category. The content presentation in the e-book includes proportional font size, type, and color, attractive illustrations, and links to valid sources relevant to the material. Revalina Hidayat et al. (2025) emphasize that effective learning media must have an attractive, communicative, and systematic appearance to aid the process of concept internalization by learners. Minor shortcomings in the visual aspect can be corrected by adjusting the arrangement of components. Meanwhile, regarding media completeness, all indicators received a maximum score (4.0), indicating a validity percentage of 100%. This shows that the e-book contains all the important components, such as the title, table of contents, instructions for use, general instructions, STEM description, concept understanding description, problem-solving skills description,

Learning Objectives and Learning Outcomes, materials, quizzes, final assessments, as well as a glossary and bibliography. According to Yanti et al. (2023) and Ediyani et al., (2020), the learning media developed must have a complete structure and content components to ensure a comprehensive learning process. This completeness allows teachers to use the media as an independent and applicable learning package. Based on the results of validation and reinforcement from expert theories, the developed e-book media have met all the criteria for validity as learning media, in terms of content, visual design, and component completeness. Revisions are only needed in minor parts related to the visual interface, without the need to overhaul the content or main structure of the e-book.

Furthermore, material validity includes material accuracy and material integration. The validation results from five subject matter experts on the STEM-based Smart E-book are presented in Table 5.

Table 5. Material Validation Results by Material Experts

Validator	Percentage (%)	Interpretation
Expert 1	98	Highly Valid
Expert 2	100	Highly Valid
Expert 3	96	Highly Valid
Expert 4	98	Highly Valid
Expert 5	100	Highly Valid
Average	98	Highly Valid

Table 6. Validation Data for Each Aspect

No	Aspect assessed	Score	Criteria
Material Accuracy			
1	The material presented is in accordance with 1) Learning Outcomes, 2) Learning Objectives, and 3) Indicators of Learning Objective Achievement.	4	Valid
2	The visualization of the material presented in the Smart E-book helps facilitate student understanding.	4	Valid
3	The material presented in the E-book is in-depth (the material covers 1) concept introduction, 2) interaction between concepts, and 3) is presented in detail.	4	Valid
4	The delivery of material in the E-book is in accordance with: 1) learner characteristics, 2) learning styles, and 3) language use appropriate for junior high school level.	4	Valid
5	The sentences used in delivering the material are simple and easy to understand.	3.4	Invalid
6	The choice of words used is appropriate for the cognitive development level of the students.	4	Valid
7	The material presented includes the four elements of STEM, namely Science, Technology, Engineering, and Mathematics.	4	Valid
8	The science content presented is appropriate, free from misconceptions, and refers to correct scientific concepts.	4	Valid
9	The activities provided in the e-book encourage critical thinking and problem-solving skills in line with the STEM approach.	4	Valid
Integration of Material			
10	There is a connection between scientific concepts and aspects of technology, engineering, and mathematics in learning.	4	Valid
11	The material is supplemented with examples, illustrations, or simulations that support in-depth understanding of the concepts.	4	Valid
12	Learning activities involve exploration, experimentation, and discussion to stimulate independent and collaborative problem solving.	4	Valid
13	Problem-solving indicators are measured through questions that test conceptual understanding and real-life application.	3.8	Valid

Material validation covers 13 indicators in two aspects, namely material accuracy and material integration. The validation results show that all indicators received high average scores, ranging from 3.4 to 4.0, with a validity percentage ranging from 85% to 100%. Most indicators are in the "Highly Valid" category, meaning that the e-book material is appropriate in terms of content, context, and learning structure. Regarding material accuracy, most indicators received a maximum score (4.0), indicating a validity percentage of 100%, which shows that the material presented is in accordance with basic competencies, conceptually accurate, and supports the achievement of science learning objectives. This is in line with Afifah (2021) opinion that learning materials must have content accuracy, scientific correctness, and contextual relevance to students' lives. One indicator, namely "The sentences used in delivering the material are simple and easy to understand," received a score of 3.4, indicating a validity percentage of 85%, in the "Highly Valid" category. However, the item needs to be revised to match the measured indicator. The suggested improvements indicate that several foreign words have not been explained directly or included in the glossary. The results of the improvements have been added with detailed explanations of foreign words, either directly or included in the glossary. In addition, the sentences used need to be simplified so that students can understand the content more easily. This is in line with the principle of cognitivism in learning theory, where presenting too complex information can hinder the information processing process (Widiyatmoko, 2023). Therefore, adjusting the style of language is important to support student comprehension. In terms of material integration, three of the four indicators received a score of 4.0 (100%), and one indicator (item 13) received a score of 3.8 (95%), remaining in the Very Valid category. Indicator 13 emphasizes that the questions presented measure problem-solving skills and relate the material to real-life contexts. This shows that the media has reflected the principles of the STEM approach, where students memorize concepts and use them to solve contextual problems. According to Rahim (2024), real-world problem-solving is an essential component of the STEM approach that encourages critical and creative thinking. The aspect of material integration, such as indicators, learning objectives, evaluation, and intermaterial relevance, has been deemed highly feasible by the validators. This reinforces Rahim (2024) view that good learning products must have a complete and organized structure so that they can be used independently by teachers and students. These results indicate that e-books are feasible for use in STEM-based learning processes at the junior high school level.

Based on suggestions from media and material experts, the revised STEM-based Smart E-book was then tested for readability. The testing was conducted in class IX A of SMP Negeri 40 Semarang, involving 35 students as samples. The purpose of the readability test was to evaluate the extent to which the STEM-based Smart E-book was easy to understand and to obtain feedback, criticism, and suggestions from students. The results of the readability test questionnaire were used to evaluate the developed Smart E-book so that it could be used as a reference in developing Smart E-books that suit students' needs. This is in line with the research by Purnomo & Palupi (2016), where questionnaires were used to provide responses or feedback on products developed according to user requests.

Table 7. Readability Test Results

Aspect	Readability	Interpretation
Material	91%	Very Good
Media	93%	Very Good
Media Usage	96%	Very Good

The readability test results based on Table 7 of the Smart E-book by students show an average percentage that falls into the "Very Good" category. The aspects with the highest scores are ease of access, attractiveness, and the ability of the media to help students understand the material on vibrations, waves, and their uses. Smart E-book was developed as a browser-based website that can be used online, making it easy and practical. In addition to containing text material, this media is also equipped with interactive images and videos to keep students focused on the learning process. Overall, the readability questionnaire results show that the STEM-based Smart E-book received positive student responses.

Figure 1. Initial Display of Media Smart E-book with a STEM Approach

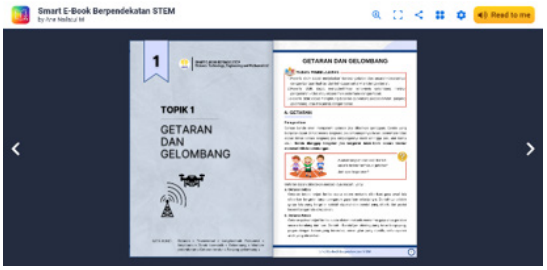

Figure 2. Material Presentation Display of Media Smart E-book with a STEM Approach

The implementation of Artificial Intelligence (AI) in this e-book is facilitated by the Vectorshift.ai platform, which is embedded to provide adaptive feedback to students. This feature allows learners to ask questions related to the learning material and receive immediate, context-relevant responses. The adaptive nature of the feedback helps students clarify misconceptions and supports independent learning. In addition, Augmented Reality (AR) technology is integrated to enhance conceptual understanding, particularly in visualizing the structure and function of the human auditory system. Through AR features, students can interact with 3D representations of the hearing organs, enabling them to observe firsthand how sound waves are received and processed. The combination of AI-driven feedback and AR-based visualization significantly improves learner engagement, comprehension, and overall usability, as reflected in the high validation scores across all assessed aspects.

Integrating advanced technologies such as Artificial Intelligence (AI) and Augmented Reality (AR) in digital learning media has enhanced student engagement, personalization, and interactivity. According to Lampropoulos (2025), AI in education supports adaptive learning systems that provide tailored feedback and individualized learning pathways, making digital media more effective in addressing students' diverse needs.

Moreover, Augmented Reality (AR) has also been demonstrated to be feasible and impactful in science learning. AR learning media is not only suitable for use but also has the potential to improve students' problem-solving abilities and conceptual understanding (Nindiasari et al., 2024). This aligns with the general function of instructional media, which serves as a tool to clarify the presentation of learning material, enhance student motivation, and bridge abstract concepts with more concrete representations. Baitha et al. (2025) and Lin et al. (2021) found that AR creates a fun, interactive, easier-to-understand learning environment and makes learning more interesting by presenting additional visual information. Aji et al. (2021) demonstrated that AR can significantly improve student learning outcomes compared to conventional methods and serve as an effective solution for learning physics. In line with this, Feri & Zulherman (2021) and Urrahmah et al., (2025) highlighted that AR benefits students and supports teachers in delivering material more effectively and designing engaging learning activities. Andi (2020) also supports these findings, indicating that augmented reality learning media for molecular shape topics are feasible, as they meet expert validity criteria and receive positive responses from both teachers and students. Moreover, the use of augmented reality–based learning media has been shown to be effective in improving students' mental models, particularly in shifting most students from the initial category to the synthetic category

Therefore, implementing AI and AR within the developed STEM-based E-book is expected to enhance its readability and practicality and broaden its pedagogical impact. By enabling adaptive feedback, immersive visualization, and interactive simulations, such integration aligns with 21st-century learning demands, particularly in fostering critical thinking, collaboration, and problem-solving skills among junior high school students.

CONCLUSION

The Smart E-book learning media with a STEM approach integrated with Artificial Intelligence (AI) and Augmented Reality (AR) technology was developed in accordance with the Research and Development (R&D) method using the 4-D model, which includes four stages: define, design, develop, and disseminate. Based on the validity test results, five experts declared the STEM-based Smart E-book learning media valid. The media aspect validity percentage reached 99.6%, while the content validity reached 98%. The results of the readability test by students were in the "Very Good" category, so it can be interpreted that the Smart E-book learning media developed is suitable for use in the learning process, with findings that also recommend further development through the expansion of material coverage and the integration of AI-based collaborative features so that e-books can be used more widely in supporting science learning at the junior high school level.

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