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Development of a Discovery Learning–Based Physics E-Book to Enhance Students' Conceptual Understanding of Sound Waves

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Abstract: *The rapid advancement of technology has profoundly influenced the field of education, particularly by enabling learning experiences that are more interactive and conceptually deep. The incorporation of mobile-based learning has emerged as a relevant approach to increase student involvement in mastering complex physics topics, such as sound waves. Accordingly, this study aims to design and evaluate a discovery learning–based physics e-book as an innovative instructional medium for senior high school students. The research adopts the 4D research and development framework—Define, Design, Develop, and Disseminate—and involves subject matter experts, media experts, and senior high school students as participants. The sampling technique used purposive sampling for experts and random sampling for students. Data collection was conducted through questionnaires and concept understanding tests, which were analyzed using descriptive statistics with reference to media feasibility criteria tables and N-Gain criteria. The results indicate that the developed e-book achieved an excellent validity level according to media and content experts and received positive feedback from users, making it highly feasible as a learning medium for physics on the topic of sound waves. An N-Gain score of 0.57 indicates a moderate increase in students' conceptual understanding, showing that the discovery learning–based physics e-book serves as an engaging alternative for enhancing learning experiences. By combining academically relevant content with local cultural values, the e-book helps students relate physics concepts to their cultural context. These findings emphasize the need for innovative and contextual learning media to improve students' understanding of physics, preserve local wisdom, and enhance the quality of physics education in Indonesia.*

Keyword*: conceptual understanding, discovery learning, e-book, sound waves*

Pengembangan *E-Book* Fisika Berbasis *Discovery Learning* untuk Meningkatkan Pemahaman Konsep Peserta Didik pada Materi Gelombang Bunyi

Abstrak: Perkembangan teknologi yang pesat telah memberikan dampak besar terhadap dunia pendidikan, terutama dalam menciptakan pengalaman belajar yang lebih interaktif dan mendalam. Penerapan pembelajaran berbasis perangkat *mobile* menjadi solusi yang semakin relevan untuk meningkatkan keterlibatan siswa dalam memahami konsep fisika yang kompleks, termasuk materi gelombang bunyi. Oleh karena itu, penelitian ini bertujuan untuk mengembangkan dan mengevaluasi *e-book* fisika berbasis *discovery learning* sebagai media pembelajaran inovatif bagi siswa sekolah menengah atas. Penelitian ini menggunakan model penelitian dan pengembangan 4D dengan melibatkan ahli materi, ahli media, serta siswa SMA sebagai subjek penelitian. Teknik pengambilan sampel yang digunakan adalah *purposive sampling* untuk para ahli dan *random sampling* untuk peserta didik. Pengumpulan data dilakukan melalui angket dan tes pemahaman konsep, yang dianalisis menggunakan statistik deskriptif dengan mengacu pada tabel kriteria kelayakan media dan kriteria *N-Gain*. Hasil penelitian menunjukkan bahwa *e-book* yang dikembangkan memiliki tingkat validitas yang sangat tinggi berdasarkan penilaian ahli materi dan ahli media, serta memperoleh tanggapan positif dari pengguna, sehingga dinyatakan sangat layak untuk diimplementasikan dalam pembelajaran fisika pada materi gelombang bunyi. Nilai N-Gain sebesar 0,57

menunjukkan peningkatan pemahaman konsep siswa pada kategori sedang, yang menandakan bahwa e-book fisika berbasis *discovery learning* dapat menjadi alternatif pembelajaran yang menarik. Dengan mengintegrasikan materi akademik dan nilai budaya lokal, *e-book* ini membantu siswa mengaitkan konsep fisika dengan konteks budaya mereka. Temuan ini menegaskan pentingnya pengembangan media pembelajaran yang inovatif dan kontekstual untuk meningkatkan pemahaman fisika siswa, melestarikan kearifan lokal, serta meningkatkan kualitas pembelajaran fisika di Indonesia.

Kata kunci: *discovery learning, e-book*, pemahaman konsep, gelombang bunyi

INTRODUCTION

Education in Indonesia continues to face persistent challenges, particularly in physics learning, where students often experience difficulties in understanding abstract and wave-based concepts such as sound waves. Sound waves involve invisible phenomena, mathematical representations, and the integration of multiple physical quantities, including frequency, wavelength, wave speed, and amplitude (OpenStax, 2024). These characteristics make the topic cognitively demanding and prone to misconceptions if not supported by appropriate instructional strategies and learning experiences (Darman et al., 2019). As a result, students frequently rely on memorization rather than conceptual understanding when learning sound waves.

Evidence from international large-scale assessments indicates that Indonesian students' scientific literacy remains relatively low. According to PISA 2018, Indonesia ranked among the lowest-performing countries in science, with an average score significantly below the OECD average (Purwoko & Parga Zen, 2023). This condition persisted in PISA 2022, which showed that Indonesian students still encounter difficulties in scientific reasoning and conceptual application (OECD, 2023). At the national level, data from the computer-based national examination (UNBK) reported by the Educational Assessment Center of the Ministry of Education and Culture revealed that students' achievement in sound wave topics remained low, particularly in Central Kalimantan Province (Kemendikbud, 2019). From 2015 to 2019, the percentage of correct responses on sound wave items did not reach the minimum mastery threshold of 55%. These data suggest that difficulties in mastering sound wave concepts persist and require targeted instructional improvement.

One major factor contributing to these learning difficulties is the continued dominance of conventional, teacher-centered instructional practices. Physics learning is often conducted through lectures that emphasize procedural problem solving and rote memorization, which tend to reduce students' motivation and limit their opportunities to construct understanding independently (Hariyanto et al., 2024). Learning approaches that do not engage students in investigation, analysis, and reasoning processes have been shown to hinder the development of critical thinking skills(Insyasiska et al., 2015; Putri et al., 2023). In contrast, active learning environments that engage students in discovering concepts through exploration and inquiry promote deeper and more durable understanding (Martaida et al., 2017). Therefore, educators must design learning experiences that position students as active participants, allowing them to independently comprehend and master physics concepts.

In response to these challenges, discovery learning is considered a pedagogical model that is particularly well suited to physics instruction, especially for abstract topics such as sound waves. Discovery learning emphasizes students' active involvement in identifying problems, exploring phenomena, formulating hypotheses, and drawing conclusions through systematic inquiry (Anggraini et al., 2018; Permatasari et al., 2018). Through investigative activities and guided experimentation, students construct knowledge based

on evidence and reasoning rather than passively receiving information. Previous studies have demonstrated that discovery learning effectively enhances students' conceptual understanding and critical thinking skills in physics (Chusni et al., 2020; Rudibyani, 2018). This approach aligns well with the nature of sound wave concepts, which require students to connect abstract representations with observable phenomena.

However, the successful implementation of discovery learning requires appropriate learning resources that can effectively facilitate exploration and conceptual construction. Several studies have reported that students' difficulties in understanding sound waves are exacerbated by the lack of suitable instructional media (Darman et al., 2019), which often results in persistent misconceptions (Jayadi et al., 2020; Manunure et al., 2020). Learning media that fail to adequately visualize wave phenomena or provide interactive learning experiences limit students' ability to meaningfully engage with abstract sound wave concepts. Recent research indicates that well-designed digital learning media can enhance students' engagement, attention, and learning outcomes by offering dynamic representations and opportunities for active involvement (Muthoharoh & Sakti, 2021; Rahman & Nyoman, 2020). Furthermore, the integration of technology in teaching sound waves has been shown to support conceptual understanding by connecting abstract physical principles with visual and contextual representations (Anggraeni et al., 2019). Innovative instructional media are key to making physics materials more engaging and relevant for students (Aritonang et al., 2017). However, in reality, many physics teachers still rely on conventional instructional media, such as chalkboards and static visual aids, which are insufficient to support discovery-oriented learning (Rina et al., 2020). Therefore, the use of appropriate and pedagogically aligned learning media is essential for effectively conveying physics concepts, particularly complex and abstract topics such as sound waves.

One type of learning media that aligns with the demands of 21st-century education and supports discovery-oriented learning is the electronic book (e-book). E-books offer advantages over printed textbooks by integrating various multimedia elements, such as text, images, audio, video, animations, and interactive features, which can enhance students' engagement and understanding (Ebied & Rahman, 2015). E-books equipped with animations and video features have been shown to improve students' comprehension of learning materials (Smeets & Bus, 2014). Empirical studies further indicate that the use of e-books contributes to improved conceptual understanding (Humairoh, 2015), better learning outcomes (Ebied & Rahman, 2015), enhanced self-directed learning skills (Ambarwati et al., 2019), increased science literacy (Suprapto et al., 2022), and greater learning interest (Novita, 2023). Despite these findings, many teachers still rely on conventional learning media, such as blackboards and static visual aids, which are insufficient to support discovery-based learning activities (Rina et al., 2020). Moreover, inadequate instructional media have been identified as a contributing factor to students' difficulties and misconceptions in learning sound wave concepts (Darman et al., 2019; Jayadi et al., 2020; Manunure et al., 2020; Martawijaya et al., 2023). This situation highlights the need for innovative instructional media that are not only interactive but also explicitly designed to align with discovery learning principles.

Therefore, this study focuses on the development of a discovery learning–based physics e-book aimed at enhancing students' conceptual understanding of sound waves. The e-book is developed using the 4D development model (Define, Design, Develop, Disseminate) to ensure systematic and high-quality instructional design (Zahroh & Yuliani, 2021). The product developed is a physics e-book on sound waves based on discovery learning, created using the Canva application and published through the Heyzine platform in the form of an HTML link. The e-book is accessible online via both computers

and smartphones, enabling flexible and independent learning. The content of the e-book includes learning outcomes, discovery learning–based instructional activities, sound wave concept materials, text- and video-based explanations, animations, interactive quizzes, and practice questions designed according to indicators of conceptual understanding. Through expert validation involving content experts, media experts, and user evaluations, this e-book is expected to meet pedagogical and technical quality standards and address the needs of both students and teachers in physics learning.

In conclusion, this research aims to contribute both theoretically and practically to physics education by providing an instructional medium that integrates the strengths of discovery learning with interactive digital technology. The findings are expected to support improvements in the quality of physics learning, particularly in enhancing students' conceptual understanding of sound waves at the secondary school level.

METHOD

This research focuses on the development of a discovery learning–oriented physics e-book as a learning medium for students. The research and development process employed the 4D model by Thiagarajan (Kurniawan et al., 2024; Latifah et al., 2020), which includes the following stages: (1) initial analysis of problems, subject needs, and literature review, (2) designing media tailored as a solution to identified issues or subject needs, (3) developing the media validated by experts and users, and (4) disseminating the media for use in teaching physics. This development research was limited to the Develop stage because the primary objective was to produce an e-book that is valid, practical, and feasible for use through expert validation and trial implementation. The Disseminate stage was not conducted due to time and resource limitations and because this study did not involve the wide distribution or large-scale implementation of the product beyond the research subjects. Instead, the research focused on evaluating the feasibility, practicality, and preliminary effectiveness of the developed e-book, while large-scale dissemination is recommended for future studies with broader scope and more comprehensive experimental research designs. Figure 1 illustrates the stages involved in the development process of the 4-D Model.

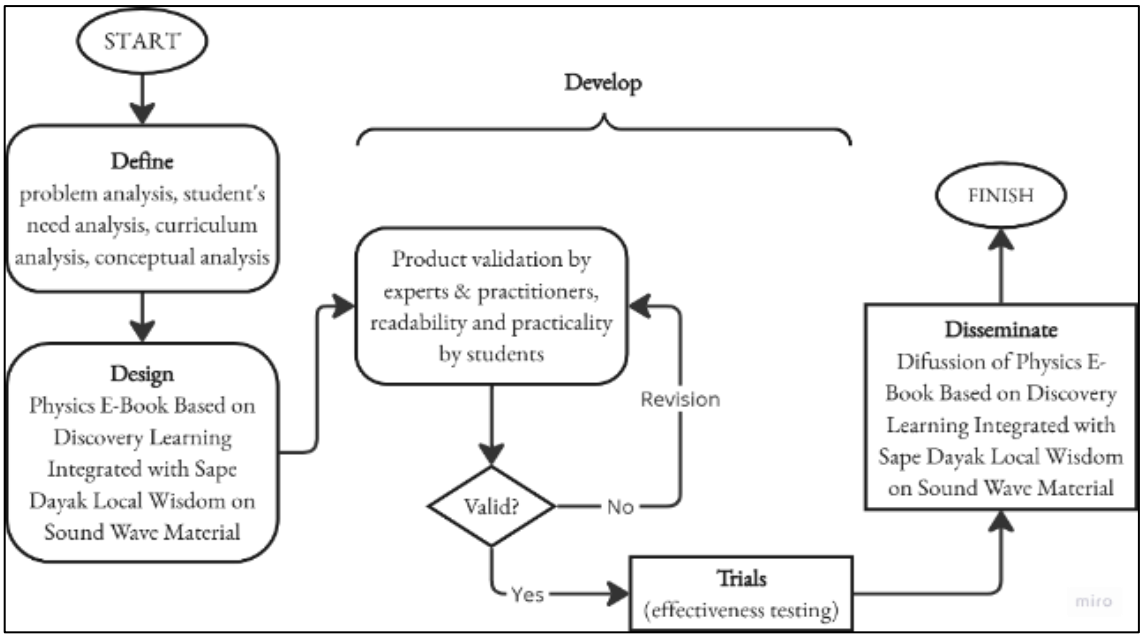

Figure 1. The Research Stages Using the 4-D Model

The study involved 7 subject matter experts, 7 media experts, and 20 students as users in the limited trial. The media and content experts consisted of three Technology Ambassadors from the Ministry of Education and Culture, one Guru Penggerak (teacher motivator) from Sukamara Regency, one chemistry teacher, one Indonesian language teacher, and one physics teacher from SMAN 1 Balai Riam. Furthermore, the limited trial was conducted with 20 eleventh-grade students of SMAN 1 Balai Riam, Central Kalimantan, who participated as users to evaluate the readability and practicality of the physics e-book. Meanwhile, the large-scale trial to measure the effectiveness of the e-book in improving conceptual understanding of sound wave material involved 32 eleventh-grade students of SMAN 1 Balai Riam, selected using a purposive sampling technique.

Data for the research were collected using questionnaires. Two types of questionnaires were employed: product feasibility questionnaires and user response questionnaires, which were adapted from the study by Sukma et al. (2019). The product feasibility questionnaires were designed to collect data on the developed product's feasibility, while the user response questionnaires gathered feedback on the suitability of the media. The product feasibility questionnaires were further categorized into media expert feasibility questionnaires and content expert feasibility questionnaires.

The data obtained in this study were examined using descriptive statistical techniques, supported by a Media Feasibility Criteria table to assess the feasibility level of the developed product. The analysis procedure was conducted through several sequential stages:

1) The mean score ($\bar{X}$) for each item across all evaluated aspects was calculated using the following formula:

$$\bar{X} = \frac{\sum X}{n} \quad (1)$$

where $\sum X$ represents the total score from all assessment aspects, and n refers to the number of evaluators or responses.

2) The mean score for each assessed aspect was transformed into qualitative data to determine the level of product feasibility. The guide for converting scores into interval scores (using a five-point scale) and interpreting these scores is based on the criteria presented in Table 1 below (Widoyoko, 2017).

Table 1. Media Feasibility Criteria

Interval Score	Category
$\overline{\mathrm{X}} > \mathrm{Mi} + 1{,}8\ \mathrm{SDi}$	Very feasible
$\mathrm{Mi} + 0{,}6\ \mathrm{SDi} < \overline{\mathrm{X}} \leq \mathrm{Mi} + 1{,}8\ \mathrm{SDi}$	Feasible
$\mathrm{Mi} - 0{,}6\ \mathrm{SDi} < \overline{\mathrm{X}} \leq \mathrm{Mi} + 0{,}6\ \mathrm{SDi}$	Quite feasible
$\mathrm{Mi} - 1{,}8\ \mathrm{SDi} < \overline{\mathrm{X}} \leq \mathrm{Mi} - 0{,}6\ \mathrm{SDi}$	Less feasible
$\overline{\mathrm{X}} \leq \mathrm{Mi} - 1{,}8\ \mathrm{SDi}$	Very less feasible

Where:

$\bar{X}$ = the mean score for each assessed aspect
Mi = mean ideal
SDi = standard deviation

The feasibility evaluation in this research was conducted with the participation of seven validators. Each evaluation item was rated on a scale ranging from 1 to 4. Referring to the criteria outlined in Table 1, the mean ideal score (*Mi*) was calculated as 17.5, while the ideal standard deviation (*SDi*) was 3.5. The classification of feasibility levels applied in this study is summarized in Table 2.

Table 2. Product Feasibility Criteria of the E-Book Based on Expert Assessment

Interval Score	Category
$\overline{X} > 23.8$	Very feasible
$19.6 < \overline{X} \leq 23.8$	Feasible
$15.4 < \overline{X} \leq 19.6$	Quite feasible
$11.2 < \overline{X} \leq 15.4$	Less feasible
$\overline{X} \leq 11.2$	Very less feasible

The improvement in students' conceptual understanding of sound waves was measured using a multiple-choice concept understanding test consisting of 20 items. These test items were designed based on concept understanding indicators adopted from the research by Kurniawan et al. (2024), encompassing interpreting, classifying, exemplifying, comparing, and explaining. These indicators correspond to cognitive skill domains and are suitable for fostering students' conceptual understanding. The detailed blueprint for the concept understanding test instrument developed for this study is summarized in Table 3.

Table 3. Blueprint of Physics Concept Understanding Test Instrument

No	Indicators of Conceptual Understanding	Topics	Number of Questions	Question Number
1	Interpreting	Characteristics of Sound Waves	4	1, 2, 3, 4
2	Classifying	Types of Sound Waves	2	5, 6
3	Exemplinifing	Applications of Sound Waves	2	7, 8
4	Comparing	Frequency of Notes on a String	4	9, 10, 11, 12
5	Explaining, comparing	Sound Intensity and Sound Intensity Level	4	13, 14, 15, 16, 17
6	Explaining	Doppler Effect	4	18, 19, 20

The data on students' conceptual understanding were analyzed using a quantitative descriptive approach to obtain numerical representations that reflect the improvement in understanding. These results were then interpreted using a qualitative descriptive analysis to provide deeper insights into the quality of the data obtained. To evaluate the effect of the physics e-book on students' conceptual understanding, a descriptive statistical analysis was conducted using the N-Gain score calculation. The use of the N-Gain score was considered appropriate because the purpose of the study was to determine the magnitude of improvement in students' conceptual understanding after the implementation of the e-book, rather than to test statistical differences or make inferential generalizations. Moreover, the one-group pretest–posttest design employed in this study supports the use of N-Gain analysis to describe the practical improvement in learning outcomes as an indicator of the e-book's preliminary effectiveness. The equation used to calculate the N-Gain score is formulated as follows.

$$\langle g \rangle = \frac{\text{posttest score} - \text{pretest score}}{\text{maximum score} - \text{pretest score}} \quad (2)$$

The results of the N-Gain Score calculation are classified into three categories as summarized in Table 4.

Table 4. The Normalized N-Gain Score Criteria

Gain Score	Category
$g \geq 0.7$	High
$0.3 \leq g < 0.7$	Moderate
$g < 0.3$	Low

RESULTS AND DISCUSSION

Results

The findings of this research indicate that the development of a discovery learning–based physics e-book on sound wave material is feasible. The development followed four principal stages—Define, Design, Develop, and Disseminate—although the implementation of this study was restricted to the development stage only.

The Define stage was the initial step to determine the conditions and requirements for developing learning tools, focusing primarily on students' needs. The main issues identified included low student engagement and participation, as well as difficulties in understanding the concept of sound waves. Consequently, there was a need for learning media and strategies that could actively involve students. The physics e-book was designed to support contextual learning using modern technology and active learning approaches. During this stage, student analysis and conceptual analysis of the physics material were conducted to understand students' characteristics and challenges in learning physics. The e-book aimed to address the lack of motivation and interest, often caused by non-innovative and non-interactive learning media. The e-book was aligned with the applicable curriculum, with a structured and systematic layout to facilitate students' understanding.

During the Design stage, the physics e-book was conceptualized with the following activities: (1) designing the e-book content on sound wave material in accordance with predetermined criteria and learning objectives, (2) selecting appropriate media to be integrated into the e-book, including images, videos, animations, and quizzes, (3) choosing the e-book format best suited to achieve the learning objectives, and (4) creating an initial storyboard or layout for the e-book, ensuring clear page organization, appropriate media selection, and user-friendly navigation.

During the Development phase, the physics e-book was produced in accordance with the conceptual framework formulated in the Design stage. This included: (1) producing the physics e-book, (2) validating the product's feasibility, and (3) conducting a development trial.

The e-book was developed as Heyzine-based media and exported in HTML format. All components outlined during the Design stage were fully incorporated into the final product. Figure 2 shows the visual representation of the developed e-book.

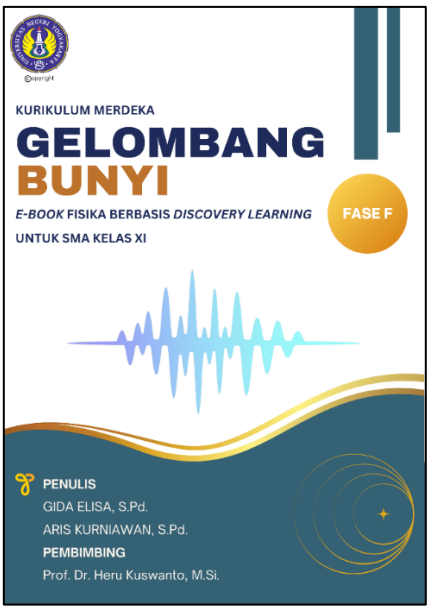

Figure 2. The E-Book Cover Design

The physics e-book on sound wave material represents a technological innovation that combines e-books, mobile learning technology, the concept of sound waves, local wisdom, and the discovery learning model. This e-book is designed to maximize the use of technology by utilizing smartphones as a learning medium. The development of this sound wave e-book integrates local wisdom into the learning process, aiming to provide a more contextual learning experience by using local culture to explain the application of physics concepts, thereby making the material more comprehensible. The e-book also employs the discovery learning model to enhance student activity and engagement during the learning process and improve their understanding of the material being taught. Discovery learning-based activities in the e-book are illustrated in Figure 3. These activities are structured to encourage students to explore, observe, and infer physics concepts interactively and independently.

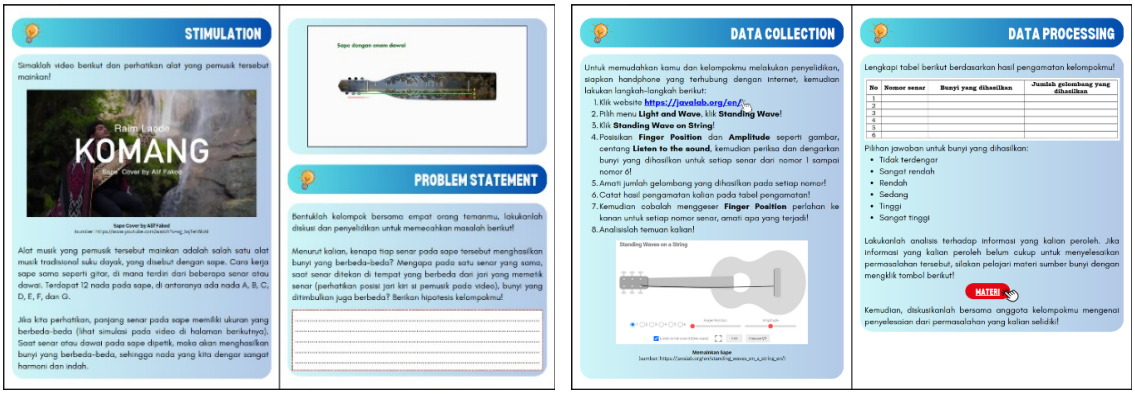

Figure 3. Discovery Activities in the Physics E-Book

The discovery and contextual problem-solving activities presented in Figure 2 are systematically structured using discovery learning syntax, facilitating students in uncovering the concepts of sound waves being studied. A learning approach that incorporates real-world contexts and group interaction is considered essential for enhancing student activity, engagement, and conceptual understanding of the material taught. This e-book integrates local wisdom from Central Kalimantan in the form of the Sape Dayak, a traditional musical instrument of the Dayak ethnic group. Although this instrument is familiar to students, its use as a physics learning medium remains limited. Through the integration of the Sape Dayak, students are guided to learn physics concepts, particularly the frequency of tones on strings. The instrument is incorporated into the e-book during the learning activities by applying the discovery learning syntax, as well as in the presentation of sound wave material, especially in the discussion of the concept of string vibration frequency. This physics e-book integrates interactive elements, including text, images, videos, animations, sample problems, and quizzes, systematically arranged to present quantities complete with symbols, units, and equations relevant to the concept of sound waves.

The discovery learning–based physics e-book for the topic of sound waves was validated to assess its feasibility as a product. This validation process aimed to evaluate the quality of the e-book by collecting feedback through questionnaires from content and media experts. The selection of experts was based on their areas of expertise. The experts involved were teachers from SMAN 1 Balai Riam, including three Technology Ambassadors from the Ministry of Education and Culture, one Guru Penggerak (Teacher Motivator) from Sukamara Regency, one Chemistry teacher, one Indonesian language

teacher, and one Physics teacher. Tables 5 and 6 present the results of the expert validation analysis.

Table 5. Results of the E-Book Validation Conducted by Topic's Content Experts

No	Assessment Aspects	Score ($\bar{X}$)	Category
1	Learning	26.4	Very feasible
2	Material Presentation	26.3	Very feasible
3	Languange Feasibility	26.0	Very feasible
Average Score		26.2	Very feasible

Table 6. Media Expert Validation Results of the E-Book

No	Assessment Aspects	Score ($\bar{X}$)	Category
1	Audio-Visual Display	24.9	Very feasible
2	Software Engineering	26.3	Very feasible
Average Score		25.6	Very feasible

Validation of the physics e-book on sound wave material was carried out with the participation of seven subject matter experts and seven media experts. The validation by content experts focused on three aspects, as shown in Table 5, namely: (1) learning aspect (five indicators), (2) material presentation aspect (six indicators), and (3) language feasibility aspect (three indicators). Based on the analysis of the evaluation data from content experts, an average score ($\bar{X}$) of 26.2 was obtained, categorized as very feasible for the developed e-book product. The validation by media experts evaluated two aspects, as shown in Table 6, namely: (1) audio-visual display aspect (seven indicators), and (2) software engineering aspect (three indicators). The data analysis revealed an average score ($\bar{X}$) of 25.6, also categorized as very feasible for the developed physics e-book.

Additionally, to assess the readability and practicality of the e-book, 20 eleventh-grade students from SMAN 1 Balai Riam in Central Kalimantan, were asked to complete a questionnaire during the limited trial. This questionnaire served as an instrument for evaluating the learning media based on user responses, using a Likert scale with four response options. The practicality categories of the developed e-book based on user assessments are presented in Table 7.

Table 7. Product Practicality Criteria of the E-Book Based on User Assessment

Interval Score	Category
$\bar{X} > 68$	Very feasible
$56 < \bar{X} \leq 68$	Feasible
$44 < \bar{X} \leq 56$	Quite feasible
$32 < \bar{X} \leq 44$	Less feasible
$\bar{X} \leq 32$	Very less feasible

Furthermore, the results of the practicality analysis of the developed e-book based on user assessments are presented in Table 8.

Table 8. User Validation Results of the Physics E-Book

No	Assessment Aspects	Score ($\bar{X}$)	Category
1	Media Display	74.17	Very feasible
2	Material Presentation	73.25	Very feasible
3	Media Operation	72.67	Very feasible
4	Media Benefit	74.20	Very feasible
Average Score		73.57	Very feasible

Table 8 shows that the readability and practicality test results for the discovery learning–based physics e-book for the topic of sound waves, as assessed by users, achieved an average score ($\bar{X}$) of 73.57, categorized as very feasible. Based on feedback from both experts and users, the physics e-book can be regarded as a practical instructional medium for sound wave material.

After the e-book was validated by experts and users, an effectiveness test was conducted in the large-scale trial using a one-group pretest–posttest design. The large-scale trial in this study was conducted using only one class without a control group because it aimed to measure the preliminary effectiveness of the developed e-book rather than to compare treatments experimentally. The study focused on evaluating the feasibility, practicality, and potential effectiveness of the learning media. The use of a single class was chosen to maintain uniformity in student characteristics, allowing improvements in conceptual understanding to be more directly attributed to the use of the e-book. In addition, time constraints and school conditions were practical considerations. Therefore, a one-class pretest–posttest design was considered sufficiently representative to indicate trends in students' conceptual understanding improvement as a basis for further development and future research using more complex experimental designs.

The procedure began with a pretest administered before the implementation of the e-book, followed by a posttest after its use in the learning process. This phase aimed to assess the improvement in students' conceptual understanding of sound waves resulting from the application of the discovery learning–based physics e-book. The research was carried out at SMAN 1 Balai Riam and involved 32 eleventh-grade students.

The analysis results indicate an improvement in students' conceptual understanding of sound waves following the implementation of instruction using the discovery learning–based physics e-book. This improvement is reflected in the increase between pretest and posttest scores and supported by the N-Gain Score analysis, which is classified in the moderate category, as summarized in Table 9.

Tabel 9. Results of Students' Conceptual Understanding Test on Sound Wave Material

	N	Min	Max	Mean	N-Gain	Criteria
Pretest	32	40	70	55.31	0.57	Moderate
Posttest	32	70	95	80.63		

The mean pretest score was 55.31, increasing to an average posttest score of 80.63, which reflects a gain of 25.32 points. The N-Gain analysis produced a value of 0.57, classified as moderate. These results indicate that the use of the discovery learning–based physics e-book effectively improves students' conceptual understanding of sound waves, with the level of improvement falling within the moderate range.

Discussion

A physics e-book developed using the discovery learning approach has been proven to effectively improve students' understanding of sound wave concepts. Validation results from content experts and media experts yielded scores of 26.2 and 25.6, respectively, both of which fall within the very feasible category, reflecting the high quality of the e-book in presenting physics content. These results align with earlier research indicating that e-books effectively improve learning skills by increasing students' interest, motivation, and active participation in the learning process learning (Aisyah & Sucahyo, 2022; Chen & Tsai, 2025; Jenny Irwansyah et al., 2024; Sari et al., 2022). This evidence further confirms that

e-books serve not only as instructional materials but also as effective media for promoting active student engagement.

Previous studies indicate that digital learning materials and inquiry- or discovery-based instructional approaches contribute positively to students' conceptual understanding and engagement in physics learning. Ethnoscience-based and STEM-integrated digital learning materials have been reported to enhance students' conceptual understanding, learning motivation, and scientific literacy (Asrizal et al., 2023; Hariyono et al., 2023). In addition, physics e-modules, including those developed for sound wave topics, are generally considered valid and practical and have been shown to increase students' learning activity (Ombili et al., 2024). Inquiry-based physics e-books have also been proven to improve students' conceptual understanding of wave topics, achieving high N-gain categories (Aisyah & Sucahyo, 2022). However, most of these studies still focus on feasibility, practicality, or general learning outcomes, without examining in depth the relationship between learning activities and the structured stages of discovery learning, particularly in the context of sound wave concepts.

This study positions its contribution in the explicit pedagogical alignment between the discovery learning model and digital media design. Unlike previous studies that emphasize interactivity as a primary feature, this research develops a discovery learning–based physics e-book on sound waves, in which multimedia elements are intentionally designed to support each stage of the discovery learning process (Chusni et al., 2020; Permatasari et al., 2018). By applying the 4D development model, which has been shown to be effective in producing high-quality instructional materials (Zahroh & Yuliani, 2021), the e-book is presented in a web-based HTML format that allows easy access across devices. This approach extends previous findings (Aisyah & Sucahyo, 2022) by positioning conceptual understanding as the primary learning outcome and by utilizing digital media and the discovery learning model to address the abstract nature of sound wave concepts, thereby offering both theoretical and practical contributions to secondary-level physics education.

The use of the discovery learning approach in this e-book was found to enhance students' conceptual understanding, as indicated by a moderately classified N-Gain score. This result is in line with the findings of Firmansyah & Subekti (2023), who reported that discovery-oriented learning models allow students to actively explore concepts, thereby supporting the development of cognitive skills and deeper understanding. Previous studies have also demonstrated that discovery learning significantly enhances students' learning outcomes (Maladerita et al., 2023; Widana & Handayani, 2022). This method emphasizes active student engagement during the learning process, which is consistent with several studies highlighting that discovery-based learning enhances students' motivation and participation (Ferguson et al., 2022; Huang et al., 2025; Satriani et al., 2021; Ummah et al., 2025). Furthermore, the integration of local wisdom in this e-book strengthens its academic relevance while providing meaningful contextual connections, enabling students to more easily comprehend the material by relating it to their cultural and everyday experiences.

The integration of local wisdom into physics e-books has been shown to positively influence students' conceptual understanding of physics. Panis et al. (2023) developed a locally based physics learning module utilizing traditional musical instruments and found that it effectively improved the conceptual understanding of tenth-grade students. Similarly, Husin & Billik (2019) reported that traditional weaving practices can be used as contextual learning resources in physics instruction, thereby making the learning experience more meaningful and relevant for students. Furthermore, Fitria Rizkiana et al. (2021) emphasized the importance of selecting engaging and relevant themes connected to

students' lives in thematic science learning. The integration of local wisdom into these themes facilitates students' understanding of the material being studied. Similarly, Astuti et al. (2022) demonstrated that presenting physics lessons in an interactive and contextual manner leaves a positive impression on students, making it easier for them to grasp complex physics concepts. Moreover, the use of teaching materials that integrate local wisdom has been shown to enhance students' mastery of physics concepts compared to conventional teaching materials (Pieter et al., 2023; Sae et al., 2021). This finding suggests that a contextual learning approach that connects instructional content with students' local experiences can enhance the effectiveness of physics instruction and support learners in better comprehending and applying physics concepts in everyday contexts.

A physics e-book integrated with local wisdom is well-suited as a more contextual learning medium. This aligns with previous research that highlights how integrating local wisdom into learning enhances the relevance and appeal of materials for students. Yasmin et al. (2023) found that learning media grounded in cultural contexts help students relate abstract concepts to real-life situations more easily. Earlier studies have also developed physics e-books integrated with local wisdom, which were deemed feasible and practical as physics learning media (Aswirna & Ritonga, 2020; Matsun, 2019; Rahayu et al., 2019; Wardani & Mundilarto, 2021). Sukma et al. (2019) highlighted that physics e-books incorporating local wisdom represent meaningful instructional resources in the Industrial Revolution 4.0 era while simultaneously supporting the preservation of local culture. Therefore, e-books that integrate local wisdom serve not only as effective physics learning media but also as instruments for safeguarding cultural heritage, aligning well with the demands of 21st-century education.

The integration of local wisdom, such as the Sape Dayak culture, in this e-book provides additional benefits in fostering students' cultural awareness and local identity. Research by Tandipau et al. (2024) emphasizes that incorporating local wisdom into learning materials not only enhances students' conceptual understanding of physics but also strengthens their cultural values. This aligns with the findings of Husin & Billik (2019), who explained that culture-based physics learning integrates cultural values into the learning process. This approach not only helps students build physics knowledge but also cultivates a scientific attitude and appreciation for their local culture.

Previous studies have demonstrated that learning media incorporating local wisdom can improve a range of student competencies, including science process skills (Pieter et al., 2023; Rahayu et al., 2019), mathematical representation abilities (Priyadi & Kuswanto, 2023; Rahmasari & Kuswanto, 2023), graphical representation skills (Rahmasari & Kuswanto, 2023), critical thinking skills (Manggul et al., 2025; Priyadi & Kuswanto, 2023), learning motivation (Fitriah et al., 2025), and scientific literacy (Aswirna & Ritonga, 2020; Batiran et al., 2025; Martawijaya & Hasyim, 2019). Learning that integrates local wisdom not only improves students' academic comprehension but also reinforces cultural values within the community (Sakti et al., 2024) and supports character formation (Hidayah et al., 2019; Layuk et al., 2023). These findings indicate that learning resources grounded in local wisdom contribute not only to deeper conceptual understanding but also to the positive development of students' character.

Feedback from users regarding the practicality of the e-book indicates that it is easy to access, user-friendly, and well accepted by students. Previous research has shown that carefully designed e-books can enhance learning experiences and help minimize misconceptions in conceptual understanding (Çırakoğlu et al., 2022; Rzyankina et al., 2024; Suriani et al., 2023). The integration of multimedia features such as animations, simulations, audio, and video content makes learning activities more engaging and

enjoyable, thereby contributing to improved learning outcomes (Alshehri, 2021; Asrowi et al., 2019). In addition, Yasmin et al. (2023) emphasized that animated learning videos enriched with cultural elements can increase students' motivation, interest, and academic achievement while also supporting positive character development. These findings highlight the necessity of developing visually appealing and interactive e-books to maximize learning effectiveness.

Within the framework of contemporary education, e-books serve as a relevant and effective form of learning media. They enable learners to access instructional content flexibly across time and place, thereby supporting the growth of self-directed learning that is increasingly essential in the digital age (Wiharjo et al., 2020). Prior research has also indicated that the use of e-books contributes to the enhancement of literacy across various disciplines, including science and mathematics (Kartiko et al., 2022). Accordingly, the development of this discovery learning–based physics e-book offers benefits beyond physics instruction by also strengthening students' overall literacy competencies.

The developed physics e-book was designed to be engaging and easy to learn. This medium provides better understanding compared to printed materials, as the content is presented in a more interactive format. Students can read, listen, watch, and follow examples through images or videos while analyzing the given problems, encouraging their active participation in learning. In this study, a locally grounded physics e-book was designed by integrating the traditional Sape Dayak musical instrument as a contextual learning resource to support students' comprehension of sound wave concepts. Overall, this study shows that the integration of Sape Dayak local wisdom into a discovery learning–based physics e-book contributes significantly to improving students' conceptual understanding of sound waves. These results align with existing literature emphasizing the effectiveness of interactive e-books in enhancing learning quality and academic success (Nugraheni & Mundilarto, 2022; Suyatna et al., 2018). As such, ongoing refinement and evaluation of e-books are vital to address the challenges of 21st-century learning.

CONCLUSION AND SUGGESTIONS

The research findings indicate that the discovery learning–based physics e-book for the topic of sound waves has been validated and deemed feasible by media experts, content experts, and users. Validation by media experts resulted in a score of 25.6, categorized as very feasible, while validation by content experts yielded a score of 26.2, also categorized as very feasible. Furthermore, the user-based practicality assessment yielded a score of 73.57, placing the e-book in the very practical category. Improvements in students' conceptual understanding of sound waves following the use of the discovery learning–based physics e-book were evidenced by an N-Gain value of 0.57, which falls within the moderate range. Accordingly, this discovery learning–based physics e-book is appropriate for use as an instructional medium for eleventh-grade senior high school students or equivalent and is effective in enhancing their understanding of sound wave concepts.

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