



Development of Differentiated E-Modules Based on Case Method Through Web Google Sites on Student Learning Outcomes on Vibration and Wave Concepts in Navigation Systems

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ABSTRACT

Purpose - This study aims to develop and test the feasibility, practicality, and effectiveness of a Case Method-Based Differentiated E-Module through the Google Sites platform. This development is intended to address the low learning outcomes of students in the Vibrations and Waves Concepts in Navigation Systems caused by the lack of laboratory facilities and teaching materials that do not accommodate the diversity of student learning profiles.

Methodology - This research is a research and development (R&D) using the 4D model (Define, Design, Develop, Disseminate). The research instruments included validation sheets from material and media experts, lecturer and student response questionnaires for practicality testing, and learning outcome tests (pretest-posttest) for effectiveness testing. The research subjects consisted of 32 students with various learning styles (visual, auditory, reading, and kinesthetic).

Findings - The results of the study indicate that the developed E-Module is very feasible to use with a V-Aiken index of 0.81 (Very Valid) from material experts and 0.78 (Quite Valid) from media experts. In terms of practicality, this product obtained a score of 86.99% from lecturer and 83.6% from students, which categorizes it as a very practical medium. The effectiveness test showed that 69% of students achieved high effectiveness criteria in improving cognitive learning outcomes after using the module.

Significance - This product serves as a reference model for educators in implementing the Independent Curriculum, which is inclusive, adaptive, and able to facilitate the personal needs of each student in understanding abstract physics concepts.

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INTRODUCTION

Science education level plays a crucial role in developing students' logical and systematic thinking skills because science learning at this level is guided by a scientific approach that fosters scientific ways of thinking, working, and communicating information (Rohmah et al., 2024). Furthermore, science learning is also considered important for training students to think logically, critically, innovatively, and creatively, and through science process skills, it can improve analytical and systematic thinking skills in observing, discussing, and drawing conclusions based on data (Abdullah, 2025; Kakiay & Wigiyanti, 2022). This demonstrates that science in SMP focuses not only on mastering concepts but also on developing a structured scientific mindset (Sukmana, Rika Widya; Rahmawati, 2025).

One of the basic competencies considered fundamental and challenging is mastery of vibration and wave material, because this material requires students not only to understand basic concepts such as period, frequency, and wave types, but also to be able to analyze the relationships between physical quantities in the context of everyday life (Salsabila, 2023). This competency is important because it is included as part of the achievement of analyzing the concepts of vibration, waves, sound, and their applications, so that students are expected to be able to identify, calculate, and present experimental results scientifically (Idawati et al., 2022). However, facts in the field show that student learning outcomes on the topic of Vibration & Waves Concepts in Navigation Systems are still far from satisfactory. Based on the results of initial observations at class, the average student daily test scores on this material are still below the Minimum Completion Criteria, with the percentage of completion only reaching 38% without remedial. The low achievement is rooted in the abstract nature of the material and the limited laboratory facilities that make it difficult to carry out real-world practicums intensively.

This situation is exacerbated by gaps in the provision of teaching materials. Currently, learning resources tend to be conventional and static, such as printed textbooks that cannot dynamically visualize wave concepts. Furthermore, lecturers face challenges in developing diverse digital teaching materials; time constraints and software complexity often lead to e-module development stalling at the static, less interactive PDF stage. As a result, students' diverse learning needs are not met, with students with visual and auditory learning styles not receiving appropriate stimulation.

Differentiated learning is present as one of the mandates in the Independent Curriculum because learning is designed to be student-centered, taking into account learning readiness, interests, and different learning profiles, so that each student can obtain a learning experience that suits their needs (Sajidah et al., 2025; Sarnoto, 2024). In practice, this approach helps teachers accommodate the diversity of student characteristics by adjusting the content, process, and learning products, while creating a more inclusive, flexible, and effective classroom (Aulia Agustin et al., 2025; Junaidin & Mirna, 2025). Thus, differentiated learning is not only a teaching strategy, but also a form of implementation of the Independent Curriculum that emphasizes respect for student diversity and optimizing each student's learning potential.

Implementing a differentiated learning strategy requires flexible media support, which can now be realized through Google Sites. This web-based platform was chosen because it is user-friendly, free, and able to integrate various multimedia features without burdening students' device memory (Adi Wicaksono & Kusuma, 2021). Through Google Sites, e-modules can be structured into differentiated learning paths according to students' learning readiness (Syifa Maulida & Hardini, 2025). To ensure higher-order thinking processes, these e-modules are integrated with the Case Method. Students not only memorize formulas but are also confronted with real-life cases, such as analyzing the working mechanism of a hearing aid or the impact of resonance on building structures. This integration aims to transform students from passive recipients of information into active problem-solvers, which theoretically strengthens cognitive retention and improves student learning outcomes (Aflah, 2024; Lesmana, 2024; Maerchy Puteri Lebang et al., 2024).

The novelty of this research lies in the synthesis of the Case Method structure with a differentiated learning framework that is accommodated in a single Google Sites web ecosystem. Unlike previous e-module development research that generally only focuses on one method or one learning style, this research

offers a hybrid solution: providing differentiated content (audio, video, and interactive simulations) while directing students to solve contextual cases. In addition, the use of Google Sites in this research provides a practical and low-cost teaching material development model for lecturers to overcome technical barriers in creating digital media. Based on this background, this study aims to analyze the development and effectiveness of a Differentiated E-Module Based on the Case Method Through the Google Sites Web in improving student learning outcomes in the Vibration and Wave Concepts in Navigation Systems material. The results of this study are expected to make a significant contribution to the innovation of inclusive, adaptive, and technology-based physics learning.

METHODOLOGY

Research Design

The research conducted was a type of R&D (Research and Development) that used the 4D model: define, design, develop, and disseminate (Thiagrajan, 1974). It is simple, systematic, and structured, making it easier for researchers to develop learning products in stages, from needs analysis to dissemination (Wahyu Sudrajat & Zulfikasari, 2026). The 4D model is also considered suitable for research on the development of learning tools because each stage is clear: define, design, develop, and disseminate, making the development process more focused and easier to evaluate. Furthermore, several studies have stated that this model has advantages because its operational steps are more detailed, practical, and suitable for developing effective media or teaching tools (Arta & Irfan, 2022). The stages of the 4D model used are presented in Figure 1.

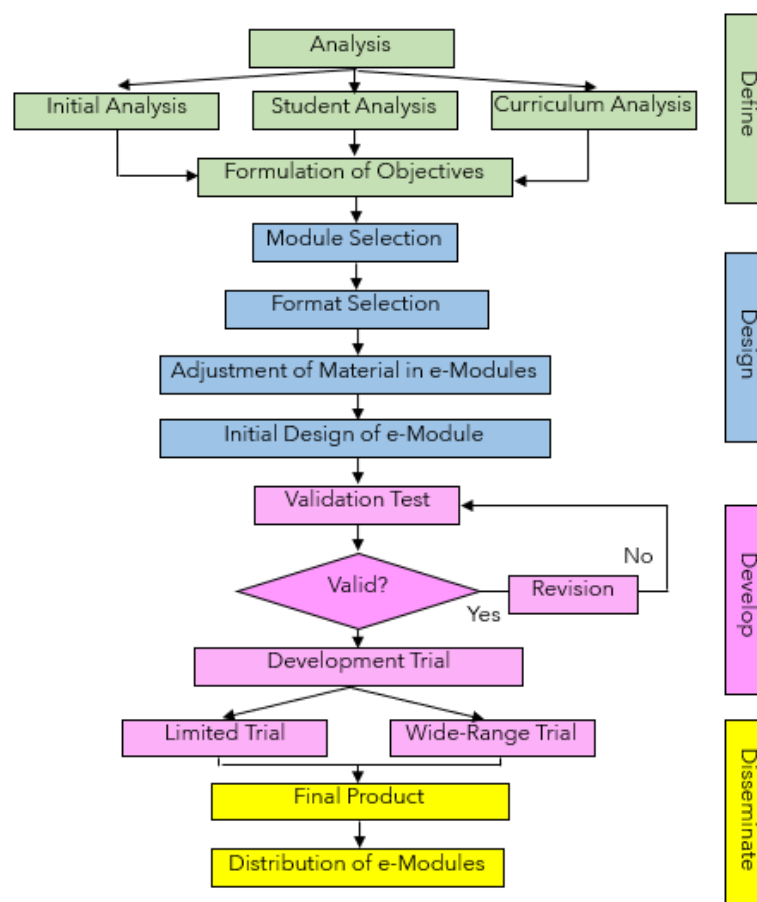


Figure 1. 4D Development Model Flowchart (Lubis et al., 2025)

Population and Sample

The research was conducted at a university in Medan city in the applied physics course. The population consisted of all students taking applied physics courses, and a sample of 32 students was selected using purposive sampling.

Data Collection, Instrument, Data Analysis for Validation

Descriptive analysis was conducted through two approaches: first, qualitative descriptive data derived from expert validation scores (materials and media), lecturer and student responses, and input in the form of comments on the questionnaire as material for product revision. Second, quantitative descriptive data in the form of percentages to present frequency data from trial subjects, validation, and effectiveness testing of the differentiated Physics e-Module based on the case method.

Research data was collected through a questionnaire addressed to two subject matter experts and two media experts as validators. This instrument uses a five-category assessment scale: Very Unsuitable (STL), Unsuitable (TL), Fairly Suitable (CL), Suitable (L), and Very Suitable (SL), with details presented in Table 1.

Table 1. Expert Validation Indicators and Grids (Mario et al., 2021)

Rated aspect	Indicator	Number of Questions
Content Suitability Aspect	A. Suitability of material with Core Competencies	3
	B. Accuracy of Material	7
	C. Update of material	4
	D. Encourage curiosity	2
Presentation Feasibility Aspect	A. Presentation techniques	2
	B. Presentation support	6
	C. Presentation of learning	1
	D. Coherence and sequence of plot	2

Table 2. Media Expert Validation Indicators and Grids (Ningtyas & Rahmawati, 2023)

Rated aspect	Indicator	Number of Questions
Expert Aspect of Graphic Feasibility Subject Matter	A. E-module size	2
	B. Cover design	7
	C. E-module content design	12
Language Feasibility Aspects	A. Straightforward	3
	B. Communicative	1
	C. Dialogic and interactive	2
	D. Language compatibility	2
	E. Suitability of symbol terms	2

The final score from the expert validation results for each assessment aspect is determined based on the Likert scale with calculations using the following formula:

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

The final score for the test set was determined based on the accumulated total score and the number of items. Meanwhile, the instrument's content validity was tested using Aiken's validity index (Aiken's V) to measure the level of agreement among expert validators. The formula used in this calculation is:

$$V = \frac{\sum s}{n(c-1)} \quad (2)$$

with,

V = Aiken V Indeks

s = the score given to each assessor minus the lowest score in the category used ($s = r - lo$)

r = score given by the validator

lo = lowest rating score

c = highest rating score

n = Number of validators

After the validator's assessment of the instrument is complete, Aiken's V-coefficient value is obtained for each aspect. This study used two validators with a five-point rating scale. An item is considered content-valid if the Aiken index falls between 0 and 1 and meets the minimum threshold based on the number of experts and assessment categories listed in Table 3.

Table 3. Aiken Validity Coefficient Classification (Retnawati, 2016)

Aiken Validity Coefficient Value (v)	Validity
$0 < V \leq 0,4$	Less Valid (Low)
$0,4 < V \leq 0,8$	Quite Valid (Medium)
$0,8 < V \leq 1$	Very Valid (High)

Data Collection, Instrument, Data Analysis for Practicality

Data collection was conducted through lecturer and student response questionnaires to test the practicality of the differentiated e-Module and evaluate the implementation of case-based learning. The questionnaire instrument was compiled based on the references in Table 4 (Nazara, Halang, & Rezeki, 2022).

Table 4. Indicators and Grids for Lecturer and Student Response Questionnaires

Rated aspect	Indicator	Number of Questions
Lecturer Response Questionnaire		
Content Suitability Aspect	A. Suitability of material with Core Competencies	3
	B. Accuracy of material	7
	C. Update of material	4
Presentation Feasibility Aspect	A. Presentation techniques	1
	B. Presentation support	6
	C. Presentation and learning	1
	D. Coherence and sequence of thought flow	2
Language Assessment	A. Straightforward	3
	B. Communicative	1
	C. Dialogic and interactive	1
	D. Appropriateness to student development	1
	E. Conformity with language rules	3
Student Response Questionnaire		
Student Response	Presentation of e-Modules	7
	Material flexibility	2
	e-Module Design	5
	Interest in e-Modules	2
	Learning components	1

This study used the Guttman scale to analyze lecturer and student response data through a checklist technique. A score of 1 was assigned to "yes" responses and a score of 0 to "no," with the final calculation based on the following formula:

$$P = f/N \times 100\%$$

With :

P = Category Percentage

f = The frequency being searched for (number of students who answered "Yes")

N = Number of students

The next step after obtaining the category percentages is to classify the scores and transform the data into percentage format. The data is then qualitatively interpreted according to the classifications listed in Table 5.

Table 5. Practicality Criteria

No	Percentage	Practicality criteria
1	86-100	Very practical
2	76-85	Practical
3	60-75	Quite Practical
4	55-59	Less practical
5	0-54	Not practical

Data Collection, Instrument, Data Analysis for Effectiveness

The effectiveness of the e-Module was measured using a multiple-choice test (pretest-posttest). The instrument initially consisted of 20 questions covering all cognitive levels of Bloom's Taxonomy (C1–C6). After validation by subject matter experts, the total number of questions used was reduced to 12, with a detailed outline shown in Table 6.

Table 6. Pretest-Posttest Grid

Main Sub-Material	Question Number and Category						Total
	C1	C ₂	C ₃	C ₄	C5	C6	
Vibration (frequency, amplitude, period)	1	2,4	6,7	10		12	6
Waves (Transverse, Longitudinal)		3	5,8	9	11		6
Total	1	3	4	2	1	1	12

The effectiveness test in this study applied the N-Gain method to measure the difference between students' pretest and posttest scores. This N-Gain score indicates the extent to which students' abilities improved after the treatment was administered. The formula used refers to Hake (1998):

$$\langle g \rangle = \frac{\langle \text{posttest score} \rangle - \langle \text{pretest score} \rangle}{\langle \text{max score} \rangle - \langle \text{pretest score} \rangle} \quad (4)$$

Table 7. Success Criteria Based on N-Gain

N-gain	Criteria
$g < 0,3$	Low
$0,3 \leq g \leq 0,7$	Medium
$g > 0,7$	High

FINDINGS AND DISCUSSION**FINDINGS****1. Define**

The define stage is a crucial initial step in establishing and defining learning requirements. Based on the analysis, several fundamental issues were identified that urgently necessitated the development of a differentiated E-Module for the Vibrations and Waves Concepts in Navigation Systems topic.

The first stage of the define implementation is the Initial-Final Analysis and Learning Outcomes. Based on the results of initial observations, it was found that student learning outcomes on the topic of Vibrations and Waves Concepts in Navigation Systems were still far from satisfactory. Data showed that the average score of students' daily tests was still below the Minimum Completion Criteria, with the percentage of completion reaching only 38% without remedial. This confirms that this material is considered challenging for students because it requires an understanding of basic concepts as well as the ability to analyze the relationship between physical quantities in everyday life. This low achievement is also rooted in the abstract characteristics of the material, which is difficult to visualize without the support of dynamic media.

The second stage is analyzing student needs and learning characteristics. The Independent Curriculum mandates that learning be designed to be student-centered, taking into account different readiness levels, interests, and learning profiles. However, the reality on the ground shows that students' diverse learning needs are not being adequately facilitated. Students with visual and auditory learning styles do not receive appropriate stimulation because the learning resources used tend to be conventional, static, and limited to printed textbooks. Therefore, media are needed that can accommodate these diverse characteristics through adjustments to content, processes, and learning products to create inclusive and effective classrooms.

The third stage, which involved analyzing lecturer facilities and constraints, identified learning outcomes challenges, including limited laboratory facilities, which made it difficult to implement intensive practical work. Furthermore, lecturers faced technical challenges in developing diverse digital teaching materials; time constraints and software complexity often led to media development stalling in static, less interactive PDF formats. Google Sites was identified as a viable solution because it is user-friendly, free, and capable of integrating multimedia features without burdening students' devices.

The final stage is curriculum analysis and goal formulation. Science learning in University level is directed to foster scientific, critical, innovative, and creative thinking. The material on Vibrations and Waves Concepts in Navigation Systems is part of the learning outcomes where students are expected to be able to identify, calculate, and present experimental results scientifically. The integration of the Case Method in the E-Module aims to transform students from passive recipients of information into active problem solvers through real-life cases, such as analyzing the mechanism of a hearing aid. This is expected to strengthen cognitive retention and directly improve student learning outcomes.

2. Design

The design phase aims to prepare a prototype learning tool as a solution to the problems identified in the define phase. The design of this e-module focuses on three main pillars: format selection, material development, and the integration of differentiation strategies and the case method.

Module Format Selection: The e-module format is designed web-based using the Google Sites platform. This selection was based on the platform's user-friendly characteristics, free of charge, and its ability to integrate multimedia features without burdening students' device memory. The navigation structure is designed to allow students to access the material non-linearly at their own pace (Islanda & Darmawan, 2023; Sri Sulistianing, Rahayu Nur A'ini, 2024).

Material Arrangement: The Vibration and Wave Concepts in Navigation Systems material is arranged by breaking down abstract concepts into smaller sub-materials, including frequency, amplitude, period, and types of waves (transverse and longitudinal). The material is not only presented in text form, but is supplemented with visuals, audiovisuals and kinesthetics according to the context of differentiation and each material is integrated with the case method.

Differentiated Learning Design: The module design accommodates diverse learning profiles by providing differentiated paths. Students are given a choice of content (videos for auditory learners, infographics for visual learners, and interactive simulations for kinesthetic learners) and can customize the learning process and products. **Case Method Integration:** The module structure is designed using a case method framework where each unit of material begins or ends with a real-life case presentation. The selected cases include analysis of the working mechanism of hearing aids and the impact of resonance on building structures to encourage active student involvement in problem solving.

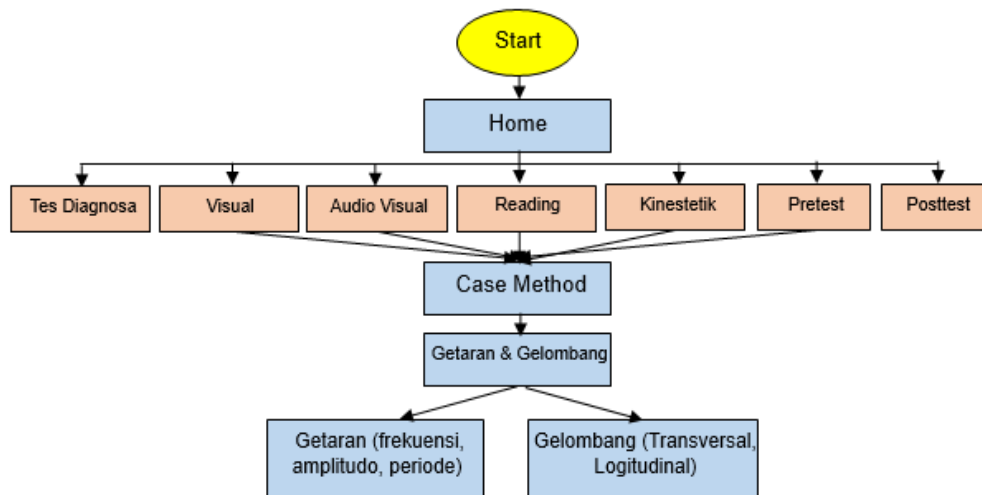


Figure 1. E-Module Arrangement Scheme and Material Arrangement

3. Development

The development phase aims to produce a revised final product based on expert input and field trials. This phase includes three main tests: validation, practicality, and effectiveness.

Validation stage

The validation process was conducted by two subject matter experts and two media experts using a Likert scale. The level of agreement between the validators was calculated using Aiken's V-index. The results of the subject matter expert validation can be seen in the following table.

Table 8. Tabulation of Results from Material Expert Validation

Validator	Aspect	V-Aiken	Criteria
1	Content Eligibility	0.81	Very Valid
2	Presentation Eligibility	0.82	Very Valid
Average		0.81	Very Valid

Table 8 presents a tabulation of the validation results conducted by two expert validators on the aspects of content feasibility and presentation feasibility of the e-module. Validator 1 (Content Feasibility) gave a V-Aiken index value of 0.81 which is included in the Very Valid criteria. This aspect includes the suitability of the material with the Basic Competencies (KD), the accuracy of the material, its currency, and the material's ability to stimulate students' curiosity. Validator 2 (Presentation Feasibility) gave a V-Aiken index value of 0.82 with the Very Valid criteria. This assessment focuses on presentation techniques, presentation support, learning presentation, and the coherence and sequence of thought processes in the e-module.

On the other hand, the results of the e-Module validation for media experts can be seen in Table 9.

Table 9. Tabulation of Results from Media Expert Validation

Validator	Aspect	V-Aiken	Criteria
1	Graphical Eligibility	0.72	Quite Valid
2	Language Eligibility	0.84	Very Valid
Average		0.78	Quite Valid

Based on Table 9, the language validation value of 0.84 indicates that the e-module has excellent language quality, is communicative, and easy for students to understand. Language quality is an important

aspect in digital teaching materials because clear language will help students grasp the learning message without causing ambiguity, especially when the material is presented through real cases that require independent analysis.

Practicality of e-Modules

Data on the practicality of the e-module was collected through an analysis of physics lecturers' and students' responses to the product. This involved 32 respondents, taking into account students' learning styles. The results of the test group analysis are shown in Table 10, and the lecturer responses are shown in Table 11.

Table 10. Student Response Test Results Data

No	Learning Style	Aspect					Average percentage (%)	Category
		1	2	3	4	5		
1	Visual	79	89	78	86	88	84.0	Practical
2	Audio visual	84	82	84	80	86	83.2	Practical
3	Reading	80	86	74	88	82	82.0	Practical
4	Kinesthetic	86	86	80	86	88	85.2	Practical
Average							83.6	Practical

Description of aspects in Table 10:

- 1 = e-Module Presentation
- 2 = Material Clarity
- 3 = e-Module Design
- 4 = e-Module Interest
- 5 = Learning Components

Based on the data presented in Table 10, the student response test results demonstrate a highly robust success rate, with an overall average of 83.6%, consistently falling within the 'Practical' category. A more detailed analysis reveals that the Kinesthetic group achieved the highest score at 85.2%, while the Reading group, despite being the lowest at 82.0%, remained highly competitive. Although minor fluctuations were observed in specific indicators such as the slightly lower score in the third aspect for the Reading group, all indicators remained within the positive zone. The stable performance of Visual (84.0%) and Audio-Visual (83.2%) learning styles further substantiates the inclusivity of the tested materials. The narrow margin between these learning preferences indicates that the instrument effectively accommodates diverse information-processing methods, making it highly feasible and practical for implementation in heterogeneous classrooms.

Meanwhile, the results of lecturers' responses to Differentiated E-Modules Based on Case Method can be seen in Table 11.

Table 11. Physics Lecturer Response Results Data

No	Aspect	Percentage (%)	Category
1	Richness of Content	83.96	Practical
2	Presentation Eligibility	88.75	Very Practical
3	Language Eligibility	88.28	Very Practical
Average		86.99	Very Practical

The results of the pilot test involving 32 respondents showed a consistent level of practicality across the spectrum of student learning profiles. Based on Table 10, the average practicality percentage from the student perspective reached 83.6%, categorized as Practical, while the assessment from the educator

perspective in Table 11 showed a higher result, with an average percentage of 86.99%, categorized as Very Practical.

Synthesis of data from the two tables confirms that the developed e-module meets operational practicality requirements. This is because the use of Google Sites as an accessible learning platform provides convenience for students because it can be accessed through a browser without the need for additional installations, so it does not burden the device's memory and is more user-friendly for digital learning. This supports the shift from static printed learning materials to digital media that is more dynamic, flexible, and easy for students to operate. Furthermore, Google Sites also allows the integration of various multimedia formats such as text, images, videos, and interactive links, thereby enriching the learning experience and making it easier for students to access materials independently (M Agil Febrian & Muhammad Irwan Padli Nasution, 2024; Ni'am et al., 2024).

Effectiveness of e-Modules

The effectiveness of the e-Module product based on a differentiated approach and the case method on the topic of Vibrations and Waves Concepts in Navigation Systems was measured through the results of a test on 32 students. This measurement used a pretest-posttest design with a 12-question instrument. The visualization of the data analysis results is presented in Figure 2.

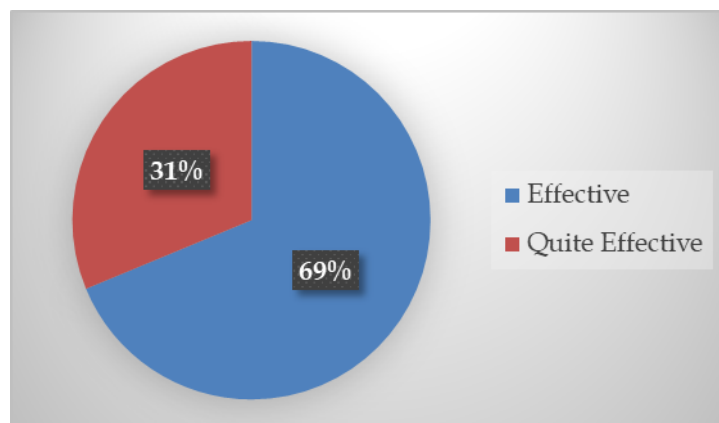


Figure 2. Visualization of the results of the N-Gain

The data analysis results in Figure 2 confirm that the Differentiated E-Module Based on the Case Method via Google Sites Web is an effective learning instrument for improving students' learning outcomes in the Vibrations and Waves Concepts in Navigation Systems material. This improvement demonstrates that the combination of practical web technology with adaptive pedagogical strategies can make a significant contribution to innovation in physics education at the secondary level.

4. Dissemination

The dissemination stage is the final phase of the 4D development model, which aims to disseminate products that have been declared valid, practical, and effective so that they can be utilized by a wider range of users. In this study, the dissemination process was carried out through several strategic channels: Limited-Scale Dissemination within Educational Units, Utilization of Web-Based Accessibility (Google Sites), Dissemination through Scientific Forums. This dissemination phase demonstrates that the developed e-module has high utility value and sustainability. Using Google Sites solves a common problem in digital media dissemination, namely the complexity of application installation; with web-based media, these technical barriers can be eliminated.

Pedagogically, the distribution of this product carries the mission of transforming physics learning in University. By disseminating the Case Method-based module, researchers encourage other educators to shift from formula-memorization-based teaching to real-world problem-solving. The positive response from

the test group (83.6% practical) and high level of effectiveness indicate that this product is ready to become a prototype for future teaching materials that are adaptive and support student diversity.

It is hoped that this dissemination will not only stop at the use of media, but also inspire other lecturers to develop similar teaching tools that are able to facilitate students' personal learning needs in order to achieve optimal learning outcomes.

DISCUSSION

The define stage demonstrated that the development of a differentiated E-Module for the Vibrations and Waves Concepts in Navigation Systems material was indeed based on real needs in the field. Initial observations showed that student learning outcomes were still low, while the Vibrations and Waves Concepts in Navigation Systems material was relatively abstract and difficult to visualize, thus requiring more dynamic learning media. From the student perspective, the implementation of the Independent Curriculum demands student-centered learning that takes into account diverse readiness, interests, and learning profiles, but conditions in class are still dominated by conventional learning resources that do not accommodate these differences. From the lecturer and facility perspective, limited laboratories and difficulties in developing interactive digital teaching materials are major obstacles, so the use of Google Sites is a relevant solution because it is free, user-friendly, and supports multimedia integration. Curricularly, science learning emphasizes scientific, critical, innovative, and creative thinking skills, while the Vibrations and Waves Concepts in Navigation Systems material requires students to be able to identify, calculate, and present experimental results scientifically; Therefore, the integration of the Case Method in the E-Module is considered appropriate to encourage students to actively solve problems through real contexts (Guntara et al., 2025; Siregar et al., 2024; Vikenso Ch. S. Taaraungan et al., 2025).

The results of this study align with previous research on the development of case-method-based e-modules, which also achieved a highly valid category based on expert assessments of content, media, and language. Other research on problem-solving-based modules shows that Aiken's V values for the material/presentation aspect are in the range of 0.66–1.00, with most items being considered highly valid. This means that the scores of 0.81–0.82 on the studied e-module are still very consistent with previous research findings, even approaching the upper limit of high validity (Hastuti et al., 2023; Hendrawensi et al., 2024; Nurdahwati et al., 2023).

The validation results show that the Case Method-based differentiated e-module has excellent content and presentation quality, as indicated by a V-Aiken value of 0.81 for content feasibility and 0.82 for presentation feasibility. These values are categorized as highly valid, meaning the material presented has been verified by experts and is suitable for use as teaching materials. The Aiken's V index is used to assess content validity, and a value close to 1 indicates a very high level of agreement between the assessment items and the constructs being measured. Therefore, these validation results confirm that the e-module content has been structured appropriately, accurately, and with minimal risk of misconception (Hastuti et al., 2023; Utami, Festiyed, et al., 2024; Utami, Ilahi, et al., 2024).

This is crucial because the Vibration and Wave material is abstract and requires a strong conceptual understanding. Physics material on Vibration and Wave often presents difficulties for students when presented verbally or through static text, necessitating teaching materials that can facilitate visualization and guide understanding gradually. Therefore, the accuracy of e-module content is not only a matter of academic feasibility but also a foundation for improving previously low student learning outcomes. Other e-module development research has also shown that high content validity is an important indicator that a product is worthy of proceeding to the next trial stage (Hendrawensi et al., 2024; Medi Zahara, 2024).

In terms of presentation, a score of 0.82 indicates that the e-module structure has been designed coherently, systematically, and supports students' thought processes. This aligns with the characteristics of differentiated learning, where different learning paths must maintain equal information quality and be well-structured to accommodate various student learning profiles. The integration of the Case Method also strengthens the presentation because students are no longer faced with merely memorizing formulas, but rather with real-life cases that require active analysis and problem-solving. In physics learning, a case-based

approach has been reported to improve students' higher-order thinking, problem-solving, and scientific communication skills (Maerchy Puteri Lebang et al., 2024; Nurdahwati et al., 2023).

When compared with references, these findings are consistent with various studies on the development of e-module-based teaching materials and the case method, which also obtained valid or very valid categories in terms of content, presentation, and media. This means that the values of 0.81 and 0.82 do not stand alone but are in line with the pattern of previous research findings (Hastuti et al., 2023; Medi Zahara, 2024; Utami, Ilahi, et al., 2024), which indicate that digital teaching materials that are systematically compiled and validated by experts tend to be feasible to proceed to the implementation stage. Thus, this e-module can be declared very feasible to be tested at the practicality and effectiveness stages.

In the context of the Case Method, communicative language functions as a bridge between cases and concepts, so that students can understand situations, identify problems, and formulate solutions in a more focused manner (Hidayati & Evy Wisudariani, 2023; Mayfa Dwi Arvi et al., 2025; Putri & Lestari, 2022). This is particularly relevant for physics materials such as bridge resonance or wave phenomena, because such cases need to be presented with simple but still scientific narratives to avoid burdening students' cognitive load. Research on the development of e-modules based on the case method also shows that appropriate and effective media generally use language presentation that is coherent, clear, and supports active student involvement. Furthermore, scientific communication literature confirms that a good understanding of language supports scientific literacy and students' ability to process scientific information (Mayfa Dwi Arvi et al., 2025; Rukiyah et al., 2025; Septia et al., 2024). Therefore, a linguistic score of 0.84 can be interpreted as an indicator that the e-module is ready for use in learning because the language used supports readability, understanding, and student interaction with the cases presented. High linguistic validity also strengthens the implementation of the Case Method, as the success of this approach depends heavily on students' ability to understand the problem context through effective and unambiguous language.

A graphical value of 0.72 indicates that the visual design on Google Sites is in the appropriate and adequate category to support the presentation of Vibrations and Waves Concepts in Navigation Systems material. Pedagogically, this result is important because vibrations and waves Concepts in Navigation Systems material contains abstract concepts, such as period, frequency, amplitude, and wave characteristics, thus requiring strong visual representations to make it easier for students to understand. The use of graphical displays, diagrams, and interactive simulations helps students build a concrete picture of concepts that were previously difficult to visualize, especially when learning is carried out without intensive laboratory practicums (Chairunisa, 2024; Salsabila, 2023). This result is also relevant to the development of Google Sites-based learning media, which shows that the platform is effective for presenting physics material interactively and improving students' conceptual understanding. With the ability to integrate multimedia and simulation links, Google Sites can be a solution to the limitations of real laboratory facilities because students can still explore concepts through visual media and virtual simulations. In the context of vibration and wave material, good graphic support can help students connect real phenomena with physics concepts, so that the learning process becomes easier, more interesting, and more meaningful (Jayanti & Handayani, 2025; Purba et al., 2024).

Overall, the average index of 0.78 indicates that the use of Google Sites as a learning platform is considered quite valid and feasible to use, so the decision to select it can be considered appropriate to support e-module development. This finding aligns with research showing that Google Sites is practical, flexible, easily accessible, and capable of containing various forms of content such as text, audio, video, and other digital learning resources that support independent learning. In the context of differentiated learning, these characteristics are crucial because students can access materials according to their readiness and learning pace without significant technical barriers (Puspitawati et al., 2024; Sari et al., 2025; Supriatna, 2024). The advantage of Google Sites is also seen in its ability to integrate multimedia and interactive learning resources, allowing different learning paths to be presented in diverse yet structured formats. This supports the principle of differentiated paths because students with visual, auditory, reading, or kinesthetic learning profiles can obtain learning experiences more tailored to their needs. Thus, the average validity value of 0.78 not only shows the feasibility of the media, but also confirms that Google Sites is effective as a learning platform that supports flexibility, independence, and personalization of student learning.

Although the language aspect has achieved the "Very Valid" predicate, the graphical score, which remains at 0.72, indicates the need for improvements in the aesthetics and visual functionality. Improvements to the content design and web navigation are expected to enhance student learning experience, which will ultimately have a positive impact on improving learning outcomes from the initial level of only 38% completion.

Pedagogically, the integration of real-life cases also strengthens independent learning because students can explore the problem, read supporting information, and then draw conclusions based on their own analysis. A good Case Method structure typically presents a clear problem flow, directed prompting questions, and adequate visual or narrative support so students can learn at their own pace. As a result, material that was initially abstract becomes closer to students' real-life experiences, and this has the potential to increase motivation, conceptual understanding, and retention of the material (Maerchy Puteri Lebang et al., 2024; Nurcahya Kasmiryanti Ar et al., 2024; Wicaksoni et al., 2013).

Judging from the personalized learning with an average practicality rating above 82% for all learning styles, this e-module has proven to be able to realize the concept of learner-centered learning. Students are no longer forced to use a uniform method (one-size-fits-all), but can instead choose the content (audio, video, or text) that best facilitates their understanding of the concept. Thus, the Differentiated E-Module Based on the Case Method is declared feasible and practical for use as an innovative and adaptive teaching tool at the University level.

Based on N-Gain analysis (Figure 2), the achievement of 69% effectiveness in the "Effective" category proves that this development product is able to overcome the problem of low learning outcomes found in the initial stage of the research. There are several main factors underlying this effectiveness: 1) Strengthening Cognitive Retention through the Case Method: The integration of the Case Method in the e-module successfully transforms students from passive recipients of information into active problem solvers. By analyzing real cases such as the working mechanism of a hearing aid or the impact of resonance on a bridge, students not only memorize formulas, but also understand physics concepts in depth. This theoretically strengthens cognitive retention and has a direct impact on improving test scores (Maerchy Puteri Lebang et al., 2024; Nurcahya Kasmiryanti Ar et al., 2024; Wijaya et al., 2024; Sutria & Harahap, 2024); 2) Optimizing Differentiated Learning: This effectiveness is also supported by the application of differentiated learning that facilitates the diversity of student learning styles (reading, visual, audiovisual, and kinesthetic). By providing differentiated content such as simulation videos and interactive texts, each student receives stimuli that suit their learning profile. This minimizes learning barriers that previously occurred due to the use of conventional, static teaching materials (Amalia & Siswanto, 2024; Asyuro et al., 2026; Raffi, Fadhila, Angle, and Intan, 2023; Yafi et al., 2025); 3) Visualization of Abstract Concepts through Google Sites: The use of Google Sites allows for the presentation of interactive simulations that can dynamically visualize the concepts of vibrations and waves. This capability is crucial considering the abstract nature of the material and limited laboratory facilities. Clear visualizations help students understand the relationships between physical quantities (such as frequency and period) more easily (Gultom et al., 2024; Gunawan et al., 2014; Hasan & Mahyudin, 2025; Munawirah et al., 2024).

CONCLUSION

Based on the results of the conducted development research, it can be concluded that; 1) Product Validity: The Differentiated E-Module Based on the Case Method via Google Sites on the topic of Vibrations and Waves Concepts in Navigation Systems was declared Highly Valid. The validation results from the material experts showed a V-Aiken index of 0.81, while the validation results from the media experts obtained an index of 0.78 (Sufficiently Valid with a testable qualification). This indicates that the material content, the integration of the case method, and the web-based media design meet the quality standards for scientific learning tools; 2) Practicality: This e-Module meets the criteria of Very Practical for use in learning. This is evidenced by the average student response of 83.6%, which encompasses various learning styles (visual, auditory, reading, and kinesthetic), and the response from physics lecturers of 86.99%. The use of the Google Sites platform has been proven to facilitate the accessibility and adaptability of teaching materials in

the University environment; 3) Effectiveness: The use of e-modules has been proven effective in improving the learning outcomes of University students. Data shows that 69% of students achieved a high level of effectiveness in understanding the Vibrations and Waves Concepts in Navigation Systems material. The integration of the Case Method and a differentiated approach transformed students into active problem solvers and accommodated the diversity of their learning needs, thus addressing the low level of learning achievement at the initial stage.

Although the results of this study demonstrate a high level of practicality, with an average success rate of 83.6%, several limitations warrant consideration when interpreting these findings broadly. First, the study's sample size was relatively limited to a single school or subject group, requiring caution when generalizing the results to a broader student population with diverse demographic and socioeconomic backgrounds. Furthermore, the data obtained relied entirely on students' subjective responses to a questionnaire, which may have been influenced by fleeting psychological factors or the desire to provide positive answers (social desirability bias), without measuring the actual impact on long-term cognitive learning outcomes. Finally, this study focused solely on learning style variables without considering other confounding variables, such as students' intrinsic motivation, digital literacy, or home technology support, which could influence the effectiveness of independent use of these learning media.

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