

## Development and Evaluation of ChatGPT-Integrated Differentiated Mobile E-Physics to Improve Student Motivation and Cognitive Performance (Pembangunan dan Penilaian E-Physics Mobile Berdiferensiasi Berintegrasi ChatGPT untuk Meningkatkan Motivasi dan Prestasi Kognitif Pelajar)

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### ABSTRACT

*This study aimed to develop and evaluate a ChatGPT-integrated differentiated mobile e-physics application for renewable energy learning. Specifically, the study examined the practicality and effectiveness of the developed application in improving students' learning motivation and cognitive performance. This study employed a Research and Development (R&D) approach using the ADDIE model, which consists of analysis, design, development, implementation, and evaluation stages. The participants of this study were 34 tenth-grade students from SMA Negeri 2 Ungaran selected through purposive sampling. The participants were selected based on their access to classroom Wi-Fi and smartphone during learning activities. Data were collected using observation sheets, cognitive tests, motivation questionnaires, practicality questionnaires, and documentation. The collected data were analyzed using descriptive percentage analysis and normalized gain (N-gain). The analysis, findings revealed that the ChatGPT-integrated differentiated mobile e-physics application was categorized as highly practical, with a practicality percentage of 79.92%. Furthermore, the application moderately improved students' learning motivation, with an N-gain score of 0.30, and cognitive performance, with an N-gain score of 0.44. These findings indicate that integrating differentiated learning and ChatGPT-assisted interaction into mobile learning environments can support more interactive, flexible, and personalized physics learning experiences.*

*Key Words: E-physics Mobile; Motivation; Cognitive Performance*

### ABSTRAK

*Kajian ini bertujuan untuk membangunkan dan menilai aplikasi e-Physics mudah alih berbeza terintegrasi ChatGPT bagi pembelajaran tenaga boleh diperbaharui. Secara khusus, kajian ini meneliti kepraktisan dan keberkesanan aplikasi yang dibangunkan dalam meningkatkan motivasi pembelajaran dan prestasi kognitif pelajar. Kajian ini menggunakan pendekatan Penyelidikan dan Pembangunan (R&D) dengan model ADDIE yang terdiri daripada lima peringkat, iaitu analisis, reka bentuk, pembangunan, pelaksanaan, dan penilaian. Peserta kajian terdiri daripada 34 orang pelajar Tingkatan 4 dari SMA Negeri 2 Ungaran yang dipilih menggunakan persampelan bertujuan. Pemilihan peserta dibuat berdasarkan akses mereka terhadap Wi-Fi bilik darjah dan penggunaan telefon pintar semasa aktiviti pembelajaran. Data dikumpulkan menggunakan lembaran pemerhatian, ujian kognitif, soal selidik motivasi, soal selidik kepraktisan, dan dokumentasi. Data yang diperolehi dianalisis menggunakan analisis peratusan deskriptif dan analisis normalized gain (N-gain). Dapatan kajian menunjukkan bahawa aplikasi e-Physics mudah alih berbeza terintegrasi ChatGPT dikategorikan sebagai sangat praktikal dengan peratusan kepraktisan sebanyak 79.92%. Selain itu, aplikasi ini menunjukkan peningkatan sederhana terhadap motivasi pembelajaran pelajar dengan skor N-gain sebanyak 0.30, serta peningkatan sederhana terhadap prestasi kognitif pelajar dengan skor N-gain sebanyak 0.44. Dapatan ini menunjukkan bahawa pengintegrasian pembelajaran terbeza dan interaksi berbantuan ChatGPT dalam persekitaran pembelajaran mudah alih mampu menyokong pengalaman pembelajaran fizik yang lebih interaktif, fleksibel, dan diperibadikan.*

*Key Words: E-physics Mobile; Motivasi; Prestasi Kognitif*

## INTRODUCTION

Education serves as a foundational element in the development of high-quality human resources by equipping individuals with knowledge, skills, competencies, values, and attitudes that contribute to national development (Muharromah & Fatmawati, 2021; Riska et al., 2021; Mukhtar & MD, 2020). Students constitute an important component within the educational system. In Indonesia, secondary education particularly Senior High School, plays a significant role in helping students develop their academic potential and competencies (Ervia et al., 2024). The implementation of the Merdeka Belajar curriculum emphasizes student-centered learning, where students are encouraged to actively participate in constructing their own understanding and learning experiences (Nurjanah & Mustofa 2024). Furthermore, the Merdeka Belajar program aims to create enjoyable and meaningful learning environments without placing excessive academic pressure on students (Zahwa et al., 2022).

Physics, as one of the major branches of science, contributes significantly to technological advancement and scientific development (Fitria et al., 2023; Amalia et al., 2024). Physics concepts are closely related to daily life and technological applications (Simamora, 2021; Sidqi et al., 2021). However, physics is often perceived as a difficult subject because many concepts are abstract and require mathematical understanding (Azahra, 2022; Astuti et al., 2019). Students frequently experience difficulties in understanding formulas, solving problems, and maintaining learning motivation during physics learning (Ady, 2022; Saiye & Bunga, 2024). Consequently, many students demonstrate low engagement and limited interest in physics learning activities. One of the important topics in physics education is renewable energy, which includes solar, wind, hydro, biomass, and geothermal energy. Renewable energy has become increasingly relevant due to environmental and sustainability concerns in modern society (Tatsar et al., 2022; Amelia & Chusni, 2024).

In physics education, improving students' learning motivation is essential because motivation strongly influences students' participation and academic achievement (Nawahdani et al., 2022). However, ineffective learning strategies, limited technology integration, and the lack of engaging learning media often reduce students' motivation during physics learning (Windayanti et al., 2023; Mea et al., 2024). Appropriate learning approaches and interactive learning environments are therefore needed to support students' motivation and conceptual understanding (Sasmita & Darmansyah, 2022). Teachers are also required to implement innovative learning strategies that align with curriculum demands and technological developments in

order to achieve effective learning outcomes (Setiani et al., 2024).

One of the potential solutions to address these challenges is the implementation of mobile learning integrated with contemporary technology. Mobile learning enables students to access learning materials flexibly through smartphones and digital devices (Lutfi et al., 2022; Sintawati & Margunayasa, 2021). Mobile learning environments provide opportunities for students to learn independently anytime and anywhere, thereby supporting flexible and student-centered learning experiences (Pebriantika et al., 2021; Karyodiputro et al., 2022). In addition, android-based mobile learning applications are widely used because they are practical, accessible, and compatible with most students' devices (Prasetyo et al., 2024; Siregar & Fikri, 2022). Along with the rapid development of educational technology, Artificial Intelligence (AI) has increasingly been integrated into learning environments. One of the most widely discussed AI technologies in education is ChatGPT, which can support interactive learning by providing explanations, answering questions, and facilitating independent learning activities. The integration of ChatGPT into mobile learning applications has potential to create more interactive and personalized learning experiences for students.

Previous studies on e-physics mobile learning have generally focused on multimedia integration and mobile accessibility without incorporating AI and differentiated learning approaches. Limited studies have integrated ChatGPT-assisted interaction into differentiated mobile learning environments in physics education, particularly in renewable energy topics. Furthermore, previous studies have rarely examined the practicality and effectiveness of ChatGPT-integrated differentiated mobile learning applications in improving students' learning motivation and cognitive performance simultaneously. Accordingly, this study aimed to develop and evaluate a ChatGPT-integrated differentiated mobile e-physics application for renewable energy learning. Specifically, this study focused on examining the practicality and effectiveness of the developed application in improving students' learning motivation and cognitive performance.

## LITERATURE REVIEW

### E-PHYSICS MOBILE

The e-Physics Mobile is a digital learning application designed to support physics learning through mobile based technology. The application functions as instructional medium that facilitate students' access learning materials, interactive activities, and multimedia resources in flexible

learning environments. Digital learning applications have been reported to improve students' engagement and support teachers in achieving instructional objectives more effectively (Puspitarini & Hanif 2019). Similarly, Nesti et al. (2022) emphasized that mobile learning applications provide interactive and flexible learning experiences that enhance students' participation during the learning process.

Developed for Android-based devices, e-Physics Mobile integrates various multimedia elements such as texts, images, videos, and interactive quizzes and simulations. These features support different learning styles and allow students to access learning materials anytime and anywhere using smartphones, thereby supporting ubiquitous learning environments (Sumiharsono et al., 2021). In physics education, multimedia integration is particularly important because many physics concepts are abstract and difficult to visualize through conventional instruction alone. Interactive videos and simulations can therefore support students' conceptual understanding and problem-solving abilities (Rodemer et al., 2021). Along with the advancement of educational technology, AI has increasingly been integrated into digital learning environments. One of the emerging AI technologies in education is ChatGPT, which can facilitate interactive learning by providing explanations, answering questions, and supporting students' independent learning activities. AI-assisted learning environments may improve students' engagement and cognitive performance because students can obtain immediate feedback and personalized learning assistance (Lin & Chen, 2024).

The integration of differentiated learning approaches into mobile learning applications also supports more personalized learning experiences. Differentiated learning allow students to access learning material according to their individual characteristics, readiness levels, and learning preferences. Therefore, integrating ChatGPT-assisted interaction and differentiated learning into e-Physics mobile may create more interactive, adaptive, and student-centered learning environments. Previous studies on e-physics mobile learning have mainly focused on multimedia integration and mobile accessibility without incorporating AI-assisted interaction differentiated learning. Therefore the development of a ChatGPT-integrated differentiated mobile e-Physics application represents an innovation in physics education, particularly in supporting renewable energy learning in the context of the Merdeka Curriculum and Society 5.0 era.

### LEARNING MOTIVATION

Learning motivation refers to the internal and external drives that encourage students to engage in learning

activities and achieve educational goals. Motivation plays an important role in determining students' participation, persistence, effort, and academic achievement during the learning process (Datu, 2022). Students with higher learning motivation tend to demonstrate greater engagement, stronger learning persistence, and better academic performance. According to Self-Determination Theory (SDT) proposed by Deci & Ryan (2000), motivation can be classified into intrinsic motivation and extrinsic motivation. Intrinsic motivation originates from students' internal interests and enjoyment in learning activities, while extrinsic motivation is influenced by external factors such as rewards, grades, and social recognition. Both forms of motivation contribute to students' learning behaviors and academic engagement.

In educational settings, learning environment and instructional strategies significantly influence students' motivation. Interactive learning media, technology integration, and supportive classroom environments can improve students' motivation by increasing engagement and participation during learning activities (Ramalingam & Jiar, 2022). In physics education, improving learning motivation is particularly important because physics is frequently perceived as a difficult and less engaging subject. Technology-assisted learning environments such as mobile learning and AI-assisted applications may support students' motivation by providing flexible access to learning materials, interactive feedback, and independent learning opportunities. Therefore, integrating ChatGPT-assisted interaction into differentiated mobile learning environments may contribute positively to students' learning motivation.

### COGNITIVE PERFORMANCE

Cognitive performance refers to students' intellectual abilities and learning outcomes acquired through educational experiences. Cognitive learning outcomes involve students' abilities to remember, understand, apply, analyze, evaluate, and create knowledge (Anderson et al., 2001). Cognitive achievement is commonly used as an indicator of students' mastery of subject matter and conceptual understanding. According to Lestari & Irawati (2020), cognitive learning outcomes describe students' understanding of factual, conceptual, and procedural knowledge obtained during instruction. Cognitive assessment is therefore essential for evaluating students' academic achievement and determining the effectiveness of instructional processes (Nurmaya et al., 2022).

Based on revised Bloom's Taxonomy proposed by Anderson et al. (2001), cognitive processes consist of six hierarchical levels: remembering, understanding, applying, analyzing, evaluating, and creating. These cognitive

dimensions represent students' progression from lower-order thinking skills to higher-order thinking skills. In physics education, cognitive learning outcomes are important because students are expected not only to memorize concepts but also to apply scientific principles, analyze problems, and develop solutions in real-life contexts (Anderson et al., 2001; Krathwohl, 2002). In renewable energy learning, cognitive development is particularly important because students need to understand scientific concepts and relate them to environmental and technological issues. Interactive and technology-assisted learning environments may support students' conceptual understanding by providing multimedia visualization, simulations, and immediate feedback during learning activities. The integration of mobile learning, differentiated learning approaches, and ChatGPT-assisted interaction may therefore support students' cognitive development by creating more interactive, adaptive, and meaningful learning experiences in physics education.

## METHODOLOGY

### RESEARCH DESIGN

This study employed a Research and Development (R&D) approach using the ADDIE development model, which consists of five stages: analyze, design, development, implementation, and evaluation. The ADDIE model was selected because it provides systematic procedures for developing educational products and evaluating their implementation in learning environments. The development procedures used in this study were adapted from Dick & Carey (1996).

#### 1. Analyze

The analysis stage aimed to identify learning problems, students' needs, and instructional objectives related to renewable energy learning at SMA Negeri 2 Ungaran. Preliminary observations and interviews with physics teachers were conducted to identify students' learning difficulties, classroom conditions, and the need for technology-assisted learning media. The analysis results indicated that students experienced difficulties in understanding abstract physics concepts and demonstrated low learning motivation during physics lessons.

#### 2. Design

The design stage focused on planning and designing the ChatGPT-integrated differentiated mobile e-Physics application. At this stage, a storyboard was developed to

describe the structure and appearance of the application, including screen layouts, navigation systems, multimedia integration, learning materials, videos, quizzes, simulations, and differentiated learning features. The application was designed to support flexible and interactive learning experiences aligned with the Merdeka Curriculum.

#### 3. Development

The development stage involved creating the mobile e-Physics application and integrating ChatGPT-assisted interaction into the learning system. After the application was developed, validation was conducted by material experts and media experts consisting of lecturers and physics teachers with expertise in educational technology and physics learning. The validation process aimed to evaluate the feasibility of the application in terms of content accuracy, instructional quality, interface design, and media functionality. Qualitative feedback and suggestions from validators were also collected to improve application before implementation. Revisions were conducted based on validators' recommendations, including improvements to visual layouts, instructional clarity, and multimedia integration.

#### 4. Implementation

The implementation stage aimed to examine the practicality and effectiveness of the developed application during physics learning activities. The implementation process involved 34 students from grade X MIPA 1 at SMA Negeri 2 Ungaran. Before the learning activities began, students completed pretests, motivation questionnaires, and diagnostic assessments. Students then participated in renewable energy learning activities using the ChatGPT-integrated differentiated mobile e-Physics application. After the implementation process, students completed posttests, motivation questionnaires, and practicality questionnaires to evaluate their learning experiences and learning outcomes.

#### 5. Evaluation

The evaluation stage was conducted to assess the overall quality of the developed application, including its feasibility, practicality, and effectiveness in supporting physics learning. The evaluation results were used to determine whether the developed application successfully supported students' learning motivation and cognitive performance in renewable energy learning.

The stages of the ADDIE development model used in this study are illustrated in FIGURE 1.

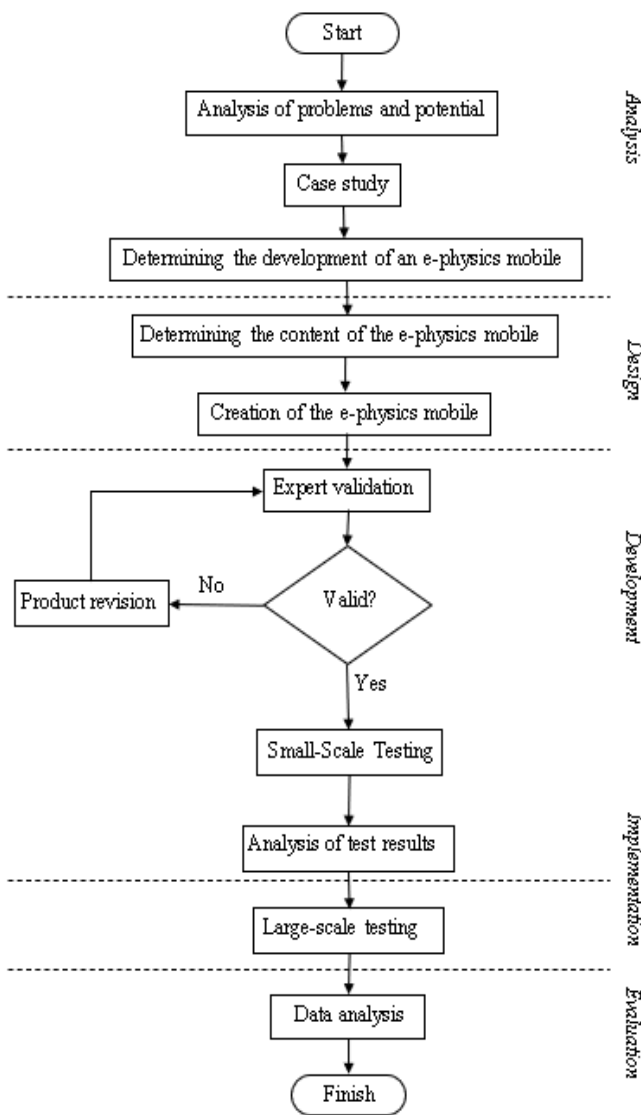


FIGURE 1. E-physics mobile development design with ADDIE model

RESEARCH SAMPLE/PARTICIPANTS

The population of this study consisted of grade X science students in Kota Semarang. The sample comprised 34 students from Class X MIPA 1 at SMA Negeri 2 Ungaran, selected using purposive sampling techniques. The sample was selected based on accessibility, available infrastructure, student’s exposure to the Merdeka Curriculum, and the availability of android smartphones required for the implementation of the mobile learning application. The purposive selection was also supported by the school’s willingness to collaborate and the identified need for more effective technology-assisted learning media in physics education. A demographic summary of the participants is presented in TABLE 1.

TABLE 1. Demographic profile of participants.

Demographic Variable	Category	Frequency	Percentage
Gender	Male	14	43.75%
	Female	18	56.25%
Learning Style*	Visual	12	37.50%
	Auditory	10	31.25%
	Kinesthetic	10	31.25%

\*Learning styles were identified using a diagnostic assessment embedded in the application.

DATA COLLECTION METHOD/ INSTRUMENTATION

This study employed interviews, test, questionnaires, and documentation as data collection methods.

1. Interview

Semi-structured interviews were conducted with physics teachers at SMA Negeri 2 Ungaran to identify classroom conditions, students’ learning difficulties, and the need for innovative learning media. The interview guidelines consisted of open-ended questions related to learning problems and instructional needs. Interview data were analyzed descriptively to support the needs analysis stage.

2. Test

Pretest and posttest were administered to evaluate students’ cognitive performance before and after the implementation of the application. The cognitive test consisted of multiple-choice questions developed based on renewable energy learning objectives. The test instrument was validated by experts, and reliability analysis using KR-20 formula indicated high reliability ( $r > 0.70$ ).

3. Questionnaire

Questionnaires were used to collect data regarding students’ motivation and practicality responses toward the developed application. The practicality questionnaire consisted of 10 items administered after implementation, while the motivation questionnaire consisted of 12 items administered before and after implementation. All questionnaire instruments were validated by experts and demonstrated acceptable reliability levels with a Cronbach’s Alpha coefficients above 0.75.

4. Documentation

Documentation included photographs of the learning activities, students’ test results, completed questionnaires and implementation records. Documentation data were used to support data triangulation and strengthen the research findings.

DATA ANALYSIS METHOD

The data analysis procedures were conducted based on each research objective. The first objective, namely the development and validation of the ChatGPT-integrated differentiated mobile e-Physics application, was analyzed descriptively using expert validation results and qualitative feedback obtained from material experts and media experts. Product feasibility was determined using percentage analysis and validators’ comments regarding content quality, interface design, instructional aspects, and multimedia integration. The second objective, namely examining the practicality of the application, was analyzed using descriptive percentage analysis obtained from students’ practicality questionnaires. The practicality results were interpreted using practicality criteria adapted from Hanisah et al. (2022), which categorized the application into very practical, practical, quite practical, and not practical categories.

The third objective, namely evaluating the effectiveness of the application in improving students’ learning motivation and cognitive performance, was analyzed using normalized gain (N-gain) analysis based on pretest and posttest results. The N-gain interpretation followed the criteria proposed by Hake (2002), namely low ( $g < 0.3$ ), moderate ( $0.3 \leq g \leq 0.7$ ), and high ( $g > 0.7$ ). All quantitative data were processed using Microsoft Excel to calculate percentages, average scores, and N-gain values. Qualitative feedback from validators and interviews was analyzed descriptively to support the interpretation of the quantitative findings.

FINDINGS AND DISCUSSION

DEVELOPMENT OF CHATGPT-INTEGRATED DIFFERENTIATED MOBILE E-PHYSICS

The development process was carried out systematically using the ADDIE model, which consists of analysis, design, development, implementation, and evaluation stages.

1. Analyze Stage

The preliminary analysis was conducted through classroom observations and interviews with physics teachers at SMA Negeri 2 Ungaran. The findings revealed that physics learning still relied heavily on printed books and PowerPoint presentations that lacked interactive features. Although students were allowed to bring smartphones to class, these devices were primarily used for communication and entertainment rather than as learning tools. In addition, classroom instruction remained dominated by conventional lecture-based methods, which reduced students’ engagement and learning motivation.

The analysis also showed that students experienced difficulties in understanding abstract physics concepts, particularly in renewable energy materials. Therefore, there was a need for interactive and technology-assisted learning media capable of supporting flexible, student-centered, and differentiated learning aligned with the Merdeka Curriculum and Society 5.0 developments. The learning objectives developed in this study focused on renewable energy concepts, including identifying renewable and non-renewable energy sources, explaining energy transformations, analyzing the law of conservation of energy, and evaluating the environmental impacts of energy utilization.

2. Design Stage

Based on the analysis results, the design stage focused on developing a storyboard for the ChatGPT-integrated differentiated mobile e-Physics application. The storyboard provided a visual overview of the application structure, including screen layouts, navigation systems, multimedia integration, learning materials, quizzes, and differentiated learning features adapted to students’ learning styles. The application was designed to support visual, auditory, and kinesthetic learning preferences through comics, videos, simulations, and interactive learning activities. In addition, ChatGPT-assisted interaction was integrated to facilitate independent learning and provide immediate responses to students’ questions during learning activities.

TABLE 2. Storyboard

Menu	Description
Intro	The introductory image is an illustration of the process of learning, accompanied by a button that initiates the start of this process. To gain access to the login page, users must press the start button.
Login and sign up	In order to gain access to the system, users are required to enter their registered email address and password. Subsequently, users must press the login button in order to gain access to the main menu of ChatGPT-integrated differentiated mobile e-physics. In the event that the requisite email and password have not been previously registered, the user is afforded the option of registering by entering the desired username, email address, and password. Subsequently, the user must register for an account by clicking the “Sign Up” button. Upon completion of the account registration process, the user may then proceed with repeating the login procedure.
Main Menu	The main menu of the ChatGPT-integrated differentiated mobile e-physics contains diagnostic assessments, evaluations, and differentiated materials, namely visual, auditory, and kinesthetic.

*continue ...*

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Menu	Description
Diagnostic Assessment	The diagnostic assessment menu contains a series of assessments designed to ascertain the learning styles of students, including visual, auditory, and kinesthetic preferences. Additionally, a left icon button serves the function of returning to the previous page.
Materials Menu	The material menu contains a set of renewable energy materials that have been developed with consideration of the varying learning styles of students. The presentation of visual material is facilitated through the use of comics and teaching materials. Subsequently, the material is presented in an auditory and kinesthetic format, utilizing video.
Evaluation menu	The evaluation menu comprises Learner Worksheets (LKPD) and evaluation questions. A left icon button is provided on this menu for returning to the previous page, namely the main menu.
The Quiz Menu	The Quiz Menu presents questions related to the subject matter of renewable energy. The quiz menu contains a button that, when selected, initiates the quiz process.
GPT Chat and Collaboration Menu	The GPT (Generative Pre-training Transformer) chat menu includes a keyboard for users to input instructions and a send button for transmitting these instructions. The collaboration menu is also similar to the GPT chat menu in that it contains a send button and keyboard. However, there is a fundamental difference between the two menus in terms of their function. The GPT chat menu is used to search for information that users require with the assistance of AI, whereas the collaboration menu serves as a space for the exchange of ideas between students and between students and teachers.
Profile Menu	The profile menu contains a variety of information, including user photos, an "About" section, a list of frequently asked questions (FAQs), instructions, a list of developers, and settings. The "About" button is utilized to ascertain information regarding the integration of ChatGPT and differentiated mobile e-physics. The FAQ button is a valuable resource for users seeking answers to frequently asked questions. The instructions button serves as a reference for operating the ChatGPT-integrated differentiated mobile e-physics application. The Developer button is used to ascertain the developer information associated with the ChatGPT-integrated differentiated mobile e-physics application. The "Settings" button is a useful feature for users who wish to exit the ChatGPT-integrated differentiated mobile e-physics application.

Table 2 presents the storyboard design of the ChatGPT-integrated differentiated mobile e-Physics application. The application consists of several main features, including diagnostic assessments, differentiated learning materials, quizzes, GPT-assisted interaction, collaboration rooms, and evaluation menus. These features were designed to support interactive, flexible, and student-centered learning experiences aligned with differentiated learning principles.

### 3. Development Stage

The development stage involved creating the ChatGPT-integrated differentiated mobile e-Physics application using Flutter and Dart programming languages. The application was developed specifically for Android devices to ensure accessibility and compatibility with students' smartphones. The developed application consisted of several main features, including diagnostic assessments, differentiated learning materials, quizzes, learner worksheets (LKPD), GPT chat, collaboration rooms, and user profile menus. Diagnostic assessments were used to identify students' dominant learning styles, while differentiated materials were presented according to visual, auditory, and kinesthetic preferences. The GPT chat feature enabled students to ask questions and obtain additional explanations related to renewable energy concepts. Meanwhile, the collaboration feature facilitated discussions among students and teachers during learning activities. Before implementation, the application underwent feasibility validation conducted by material experts and media experts. The material validation results are presented in TABLE 3.

TABLE 3. Results of feasibility validation of e-physics mobile materials

Number	Validation code	Percentage	V-aiken's	Criteria
1	DS-01	93%	0.88	Very valid and Very feasible
2	DS-02	90%		
3	GR-01	90%		
4	GR-02	85%		
5	GR-03	92%		

The material validation results presented in Table 3 indicate that the developed application achieved an average feasibility percentage of 90% with an Aiken's V coefficient of 0.88, categorized as highly valid and highly feasible. These findings indicate that the renewable energy materials integrated into the application fulfilled instructional quality standards and were appropriate for implementation in physics learning activities. The media validation results are presented in TABLE 4.

TABLE 4. Results of feasibility validation of e-physics mobile.

Number	Validation Code	Percentage	V-aiken's	Criteria
1	DS-01	89%	0.90	Very Valid and Very Feasible
2	DS-02	97%		
3	GR-01	91%		
4	GR-02	86%		
5	GR-03	92%		

The media validation results presented in Table 4 show that the application achieved an average feasibility percentage of 91% with an Aiken's V coefficient of 0.90, categorized as highly valid and highly feasible. These findings indicate that the developed application fulfilled technical and visual quality standards required for mobile learning implementation.

In addition to quantitative validation results, validators also provided qualitative suggestions for improvement. Several revisions were conducted to improve the quality of the application, as presented in TABLE 5.

TABLE 5. E-physics mobile improvements

Validator	Improvement
Material Expert	The display of images and videos has been enhanced.
	The number of questions on the competency test has increased from 10 to 15, while the number of quiz questions has increased from 6 to 10.
	Practice questions have been revised to emphasise the application of technology.
	Corrections have been made to some sentences that were still typos, and the spacing has been adjusted accordingly.
Media Expert	The appearance of the diagnostic assessment menu is made more proportional in accordance with the theme of the application being made, in addition to adjusting the font in the final results of the diagnostic assessment.
	Icon that is not in accordance with its function has been corrected.
	There is a description of the video source used in learning.
	Some font sizes that look small are corrected by considering the proportionality aspect of the display.
	In the LKPD made, instructions for use have been added.

Based on expert suggestions, the revisions mainly focused on improving multimedia quality, interface proportionality, instructional clarity, practice questions, and learning activity guidance. These improvements were intended to optimize the usability and instructional effectiveness of the developed application before classroom implementation. The findings of this study strengthen previous studies regarding mobile learning in physics education by demonstrating that the integration of ChatGPT-assisted interaction and differentiated learning strategies can provide more adaptive and personalized learning experiences. Unlike previous studies that mainly focused on multimedia integration, the present study emphasizes the role of artificial intelligence in facilitating interactive learning support and individualized feedback.

#### 4. Implementation and Evaluation Stage

The implementation stage involved 34 Grade X students at SMA Negeri 2 Ungaran during renewable energy learning activities. Before the learning process, students completed pretests, motivation questionnaires, and learning style diagnostic assessments. The diagnostic assessment results revealed that 14 students had visual learning styles, 13 students had auditory learning styles, and 7 students had kinesthetic learning styles. Students then participated in learning activities using the ChatGPT-integrated differentiated mobile e-Physics application with a problem-based learning approach. Learning activities included group discussions, renewable energy analysis, multimedia-based learning, differentiated instruction, and interactive learning using ChatGPT-assisted features. After implementation, students completed posttests, motivation questionnaires, and practicality questionnaires. The evaluation stage focused on examining the practicality and effectiveness of the developed application in improving students' learning motivation and cognitive performance.

#### EFFECTIVENESS OF CHATGPT-INTEGRATED DIFFERENTIATED MOBILE E-PHYSICS ON STUDENTS' LEARNING MOTIVATION.

The effectiveness of the ChatGPT-integrated differentiated mobile e-Physics application in improving students' learning motivation was measured using pretest and posttest motivation questionnaires. The increase in motivation was analyzed using normalized gain (N-gain) analysis. The results indicated that students' learning motivation increased moderately, with an N-gain score of 0.30.

TABLE 6. N-gain analysis of learning motivation

Component	Value		N-gain	Kriteria
	Pretest	Posttest		
Number of students	34	34	0.30	Medium
Highest score	38	39		
Lowest score	24	27		
Average	29.86	32.86		

The findings presented in TABLE 6 indicate a moderate improvement in students' learning motivation after the implementation of the developed application, with an N-gain score of 0.30. These findings suggest that the integration of differentiated learning features and ChatGPT-assisted interaction positively contributed to students' engagement during renewable energy learning activities. The moderate increase in learning motivation indicates that interactive and technology-assisted learning environments can encourage students to participate more actively in classroom learning. The flexibility of mobile learning also enabled students to access learning materials independently anytime and anywhere, supporting more student-centered learning experiences.

These findings are consistent with previous studies reporting that Android-based mobile learning can improve students' learning motivation and engagement during classroom instruction (Khefrianti, 2021; Poçan et al., 2023). However, the present study extends previous research by emphasizing the contribution of artificial intelligence and differentiated learning in supporting student-centered learning environments. The findings also align with studies conducted by Lo (2023), Kasneci et al. (2023), and Tlili et al. (2023), which reported that generative artificial intelligence can enhance students' learning engagement, provide personalized learning assistance, and support adaptive educational experiences. Further analysis based on motivation indicators showed in FIGURE 2.

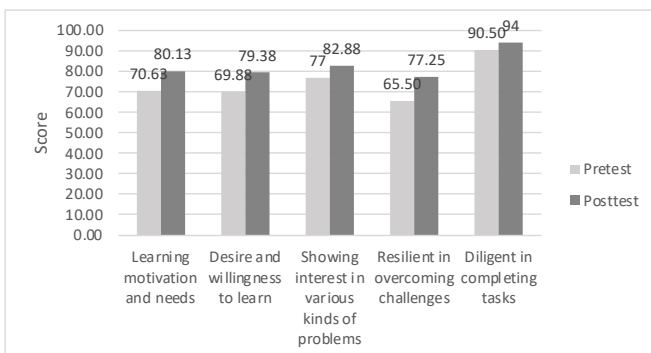


FIGURE 2 Learning motivation for each indicator (Nasrah, 2020)

The indicator of perseverance in facing tasks demonstrated the highest increase with an N-gain score of 0.34, categorized as moderate. This finding indicates that students became more enthusiastic in completing assignments and learning activities after using the application. Meanwhile, the indicator of interest in solving different types of problems demonstrated the lowest increase with an N-gain score of 0.26. Although the increase remained within the low category, the result still suggests that students experienced gradual improvement in responding to challenging learning tasks. The relatively lower improvement may have been influenced by students' limited prior experience with problem-solving activities and graph interpretation tasks.

#### EFFECTIVENESS OF CHATGPT INTEGRATED DIFFERENTIATED MOBILE E-PHYSICS ON STUDENTS' COGNITIVE PERFORMANCE.

Students' cognitive performance was measured using pretest and posttest cognitive tests consisting of 15 multiple-choice questions related to renewable energy concepts as showed in TABLE 7. The increase in cognitive performance was analyzed using N-gain analysis. The findings revealed that students' cognitive performance increased moderately, with an N-gain score of 0.44.

TABLE 7. N-gain analysis of students' cognitive level

Component	Score		N-gain	Criteria
	Pretest	Posttest		
Number of students	34	34	0.44	Medium
Highest score	8	10		
Lowest score	1	3		
Average	4.53	9.14		

The moderate improvement in cognitive performance indicates that the developed application effectively facilitated students' understanding of renewable energy concepts. The differentiated learning approach allowed students to access learning materials according to their preferred learning styles, thereby improving conceptual comprehension. The findings support previous studies indicating that differentiated and technology-assisted learning can improve students' academic achievement, conceptual understanding, and independent learning skills (Tomlinson, 2017; Hwang & Fu, 2019). However, this study further demonstrates that integrating ChatGPT into mobile learning environments can provide additional learning support through interactive explanations, immediate feedback, and adaptive assistance (Kasneci et al., 2023; Zhai, 2023). Further analysis of cognitive indicators is presented in FIGURE 3.

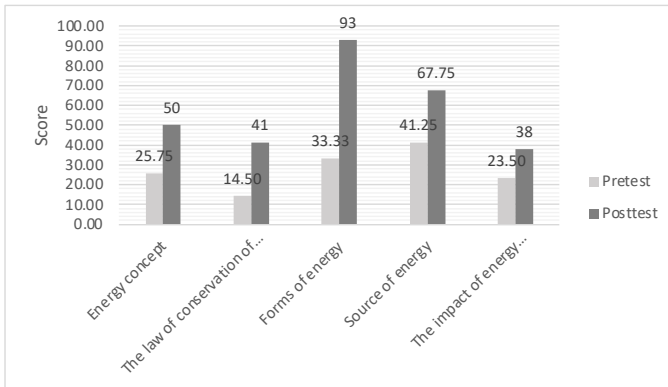


FIGURE 3. Students' cognitive level for each essential matter (Puspaningsing et al., 2021)

In Figure 3, further analysis based on essential renewable energy topics revealed that the highest improvement occurred in the energy forms topic with an N-gain score of 0.90, categorized as high. Students demonstrated strong understanding in identifying forms of energy and explaining energy transformations. Meanwhile, the lowest improvement occurred in the topic concerning the impact of energy exploration and environmental sustainability, with an N-gain score of 0.19. Students still experienced difficulties in interpreting graphs and analyzing environmental impacts critically. This finding suggests that higher-order thinking skills and graph interpretation abilities require more intensive instructional support.

These findings are consistent with previous studies indicating that students often experience difficulties in interpreting scientific graphs and applying statistical reasoning during physics learning. Therefore, future learning designs should provide additional scaffolding activities to improve students' analytical and interpretative skills. Overall, the findings of this study indicate that the ChatGPT-integrated differentiated mobile e-Physics application successfully fulfilled the research objectives by demonstrating high feasibility, practical implementation, and moderate effectiveness in improving students' learning motivation and cognitive performance in renewable energy learning. The integration of differentiated learning strategies and artificial intelligence-assisted interaction contributed to more flexible, adaptive, and student-centered learning experiences, which are increasingly emphasized in contemporary digital education research (Lo, 2023; Tlili et al., 2023; Zhai, 2023).

#### PRACTICALITY OF CHATGPT-INTEGRATED DIFFERENTIATED MOBILE E-PHYSICS APPLICATION

The practicality of the developed application was evaluated using a student response questionnaire administered after

the implementation stage. The practicality assessment consisted of four indicators, namely ease of use and navigation, cognitive content, presentation of information, and ease of relearning. The results showed that the application achieved an average practicality score of 79.92%, categorized as practical.

TABLE 8. Results of e-physics mobile practicality test analysis

Number	Practicality Indicator	Percentage	Criteria
1	Ease of Use and Navigation	77.94	Practical
2	Cognitive Content	78.97	Practical
3	Presentation of Information	80.59	Very Practical
4	Ease of Relearning	83.14	Very Practical
	Average	79.92	Practical

Table 8 shows that students responded positively to the application because it provided flexible learning opportunities that could be accessed anytime and anywhere through smartphones. Students also perceived the learning materials, quizzes, and ChatGPT interaction features as engaging and supportive for independent learning. The highest practicality score was found in the ease of relearning indicator (83.14%). This finding suggests that the mobile learning application effectively supported repeated learning activities and self-paced learning experiences. The integration of interactive multimedia and AI-assisted learning support enabled students to revisit learning materials more efficiently.

These findings are consistent with previous studies indicating that mobile learning applications can increase students' engagement, flexibility, and learning accessibility (Crompton & Burke, 2018; Hwang & Fu, 2019). Furthermore, the integration of ChatGPT-assisted interaction supports more adaptive and responsive learning environments by providing immediate feedback and personalized assistance during learning activities (Kasneci et al., 2023; Lo, 2023; Tlili et al., 2023).

#### CONCLUSION

This study aimed to develop and evaluate a ChatGPT-integrated differentiated mobile e-Physics application to enhance students' learning motivation and cognitive performance in renewable energy learning. The application was designed to accommodate students' visual, auditory, and kinesthetic learning preferences through differentiated learning features and interactive multimedia content. The

findings revealed that the developed application achieved high feasibility based on expert validation results, with material feasibility reaching 90% and media feasibility reaching 91%, both categorized as highly feasible. In terms of practicality, students' responses indicated that the application was practical for classroom implementation, achieving an average practicality score of 79.92%.

Furthermore, the effectiveness analysis demonstrated that the application moderately improved students' learning motivation and cognitive performance, with N-gain scores of 0.30 and 0.44, respectively. These findings suggest that integrating ChatGPT-assisted interaction with differentiated mobile learning can support more engaging, flexible, and student-centered physics learning experiences. This study contributes to the growing implementation of artificial intelligence in education, particularly in supporting differentiated learning approaches in physics education. The integration of ChatGPT within mobile learning environments provides opportunities for more personalized learning experiences and interactive knowledge construction. However, this study was limited by the relatively small sample size, implementation within a single school context, and the short duration of implementation. Therefore, future studies are recommended to involve larger and more diverse samples, longer implementation periods, and broader learning contexts to examine the long-term effectiveness of ChatGPT-integrated differentiated learning applications and their impact on students' higher-order thinking skills.

## REFERENCES

- Ady, W. N. (2022). Analisis Kesulitan Belajar Siswa SMA terhadap Mata Pelajaran Fisika pada Materi Gerak Lurus Beraturan. *Jurnal Pendidikan dan Ilmu Fisika*, 2(1), 104. <https://doi.org/10.52434/jpif.v2i1.1599>
- Amalia, S. H., Purwanto, A., & Risdianto, E. (2024). Pengembangan Media Pembelajaran Game Edukasi Fisika (GEMIKA) Berbantuan Wordwall untuk Meningkatkan Motivasi Belajar Siswa SMA. *Jurnal Penelitian Pembelajaran Fisika*, 15(2), 222–232. <https://doi.org/10.26877/jp2f.v15i2.18099>
- Amelia, N., & Chusni, M. M. (2024). Analisis Keterampilan Berpikir Kritis dalam Pembelajaran Fisika Pada Materi Energi Terbarukan. *BIOCHEPHY: Journal of Science Education*, 4(1), 248–252. <https://doi.org/10.52562/BIOCHEPHY.V4I1.1114>
- Anderson, L. W., Krathwohl, D. R., & Bloom, B. S. (2001). *A Taxonomy For Learning, Teaching, And Assessing: A Revision Of Bloom's Taxonomy Of Educational Objectives*. Longman. <https://archive.org/details/taxonomyforlearn0000unse>
- Astuti, B., Astuti, I. N., Sulhadi, Darsono, T., & Wahyuni, S. (2019). Analysis of The Responses on The Developing Torricelli Tube Experiment Based on The Waste Materials. *Journal of Physics: Conference Series*, 1170(1). <https://doi.org/10.1088/1742-6596/1170/1/012030>
- Azahra, A. C. (2022). Pengembangan E-LKPD Fisika Berbasis Animasi pada Materi Hukum Newton. In *MAGNETON: Jurnal Inovasi Pembelajaran Fisika* 3(1). <https://doi.org/10.30822/MAGNETON.V3I1.3945>
- Crompton, H., & Burke, D. (2018). The Use Of Mobile Learning In Higher Education: A Systematic Review. *Computers and Education*, 123, 53–64. <https://doi.org/10.1016/j.compedu.2018.04.007>
- Datu, A. R. (2022). Pengaruh Motivasi Belajar Terhadap Hasil Belajar Siswa. *Jurnal Basicedu*, 6(2), 2541–2549.
- Deci, E. L., & Ryan, R. M. (2000). The “What” And “Why” Of Goal Pursuits: Human Needs And The Self-Determination Of Behavior. *Psychological Inquiry*, 11(4), 227–268. [https://doi.org/10.1207/S15327965PLI1104\\_01](https://doi.org/10.1207/S15327965PLI1104_01)
- Dick, W., & Carey, L. (1996). *The Systematic Design of Instruction (4th ed.)*. New York: Harper Collins.
- Ervia, E., Harahap, R. D., & Chastanti, I. (2024). Analisis Perkembangan Kurikulum Biologi dari kurikulum 1984 Sampai dengan Kurikulum Merdeka. *Didaktika: Jurnal Kependidikan*, 13(1), 927–936. <https://doi.org/10.58230/27454312.491>
- Fitria, N., Asshaumi, R. U., Putri, Y. D. A., Herman, N. B., Handayani, R. D., & Putra, P. D. A. (2023). Analisis Efektivitas E-Learning Sebagai Media Pembelajaran Fisika Pada Siswa Sma. *OPTIKA: Jurnal Pendidikan Fisika*, 7(1), 167–176. <https://doi.org/10.37478/optika.v7i1.2792>
- Hake, R. R. (2002). Relationship Of Individual Student Normalized Learning Gains In Mechanics With Gender, High-School Physics, And Pretest Scores On Mathematics And Spatial Visualization. *Physics Education Research Conference*, 8, 1–14. [https://scholar.google.com/citations?view\\_op=view\\_citation&hl=en&user=10EI2q8AAAAJ&citation\\_for\\_view=10EI2q8AAAAJ:IjCSPb-OGe4C](https://scholar.google.com/citations?view_op=view_citation&hl=en&user=10EI2q8AAAAJ&citation_for_view=10EI2q8AAAAJ:IjCSPb-OGe4C)
- Hanisah, Irhasyurna, Y., & Yulinda, R. (2022). Pengembangan Media Pembelajaran Interaktif Menggunakan Ispring Suite 10 Pada Materi Reproduksi Tumbuhan Untuk Mengukur Hasil Belajar. *JUPEIS: Jurnal Pendidikan dan Ilmu Sosial*, 1(3), 6–16. <https://doi.org/10.55784/jupeis.vol1.iss3.68>
- Hwang, G. J., & Fu, Q. K. (2019). Trends In The Research Design and Application of Mobile Language Learning: A Review Of 2007–2016 Publications in Selected SSCI Journals. In *Interactive Learning Environments* 27(4), 567–581. Routledge. <https://doi.org/10.1080/10494820.2018.1486861>
- Karyodiputro, M. I., Hidayat, F. N., & Ningsih, S. W. (2022). Implementasi Pembelajaran Online Berbasis

- Web dan Android dalam Peningkatan Karakter Peserta Didik di MI At-Taqwa Bondowoso. *Auladuna : Jurnal Prodi Pendidikan Guru Madrasah Ibtidaiyah*, 4(1), 1–14. <https://doi.org/10.36835/au.v4i01.1088>
- Kasneji, E., Sessler, K., Küchemann, S., Bannert, M., Dementieva, D., Fischer, F., Gasser, U., Groh, G., Günemann, S., Hüllermeier, E., Krusche, S., Kutyniok, G., Michaeli, T., Nerdel, C., Pfeffer, J., Poquet, O., Sailer, M., Schmidt, A., Seidel, T., ... Kasneji, G. (2023). Chatgpt For Good? On Opportunities And Challenges Of Large Language Models For Education. *Learning and Individual Differences*, 103, 102274. <https://doi.org/10.1016/j.lindif.2023.102274>
- Khefrianti, S. (2021). Pengembangan Mobile Learning Ikatan Kimia untuk Meningkatkan Motivasi dan Hasil Belajar Siswa. *Jurnal Guru Dikmen dan Dikus*, 4(2), 191–207. <https://doi.org/10.47239/jgdd.v4i2.352>
- Krathwohl, D. R. (2002). A revision of bloom's taxonomy: An overview. In *Theory into Practice* 41(4), 212–218. Ohio State University Press. [https://doi.org/10.1207/s15430421tip4104\\_2](https://doi.org/10.1207/s15430421tip4104_2)
- Lestari, D. G., & Irawati, H. (2020). Literature Review : Peningkatan Hasil Belajar Kognitif Dan Motivasi Siswa Pada Materi Biologi Melalui Model Pembelajaran Guided Inquiry. *Bioma*, 2(2), 51–59. <https://ojs.unsulbar.ac.id/index.php/bioma/article/view/861>
- Lin, H., & Chen, Q. (2024). Artificial intelligence (AI)-integrated educational applications and college students' creativity and academic emotions: students and teachers' perceptions and attitudes. *BMC Psychology*, 12(1). <https://doi.org/10.1186/s40359-024-01979-0>
- Lo, C. K. (2023). What Is the Impact of ChatGPT on Education? A Rapid Review of the Literature. *Education Sciences*, 13(4), 410. <https://doi.org/10.3390/educsci13040410>
- Lutfi, A., Saad, M., Almaiah, M. A., Alsaad, A., Al-Khasawneh, A., Alrawd, M., Alsyof, A., & Al-Khasawneh, A. L. (2022). Actual Use of Mobile Learning Technologies during Social Distancing Circumstances: Case Study of King Faisal University Students. *Sustainability (Switzerland)*, 14(12), 7323. <https://doi.org/10.3390/su14127323>
- Mea, F., Tinggi, S., Kristen, A., & Bangsa, A. (2024). Peningkatan Efektivitas Pembelajaran Melalui Kreativitas Dan Inovasi Guru Dalam Menciptakan Kelas Yang Dinamis. *Inculco Journal of Christian Education*, 4(3), 252–275. <https://doi.org/10.59404/IJCE.V4I3.190>
- Muharromah, S. I., & Fatmawati, N. (2021). Peningkatan Pembelajaran IPS di MTs/SMP Berbasis Kurikulum 13 dalam Membentuk Sumber Daya Manusia yang Unggul dan Berkarakter. *ENTITA: Jurnal Pendidikan Ilmu Pengetahuan Sosial dan Ilmu-Ilmu Sosial*, 3(2), 197–212. <https://doi.org/10.19105/ejpis.v3i2.5224>
- Mukhtar, A., & MD, L. (2020). Pengaruh Kompetensi Guru Terhadap Kinerja Guru Dan Prestasi Belajar Siswa Di Kota Makassar. *Idaarah: Jurnal Manajemen Pendidikan*, 4(1), 1. <https://doi.org/10.24252/idaarah.v4i1.13899>
- Nasrah, A. M. (2020). Analisis Motivasi Belajar dan Hasil Belajar Daring Mahasiswa Pada Masa Pandemi Covid-19. *Riset Pendidikan Dasar*, 3(2), 207–213.
- Nawahdani, A. M., Triani, E., Azzahra, M. Z., Maison, M., Kurniawan, D. A., & Melisa, D. (2022). Hubungan Minat dan Motivasi Belajar Siswa terhadap Mata Pelajaran Fisika. *Jurnal Penelitian dan Pengembangan Pendidikan*, 6(1), 12–18. <https://doi.org/10.23887/jppp.v6i1.41986>
- Nesti, E. W., Medriati, R., & Purwanto, A. (2022). Analisis Kebutuhan Pengembangan Media Pembelajaran Fisika Berbasis Aplikasi Lectora Inspire. *Jurnal Ilmiah Pendidikan Fisika*, 6(2), 379. <https://doi.org/10.20527/jjpf.v6i2.5144>
- Nurjanah, E. A., & Mustofa, R. H. (2024). Transformasi Pendidikan: Menganalisis Pelaksanaan Implementasi Kurikulum Merdeka pada 3 SMA Penggerak di Jawa Tengah. *Didaktika: Jurnal Kependidikan*, 13(1), 69–86. <https://mail.jurnaldidaktika.org/contents/article/view/419>
- Nurmaya, E., Rusilowati, A., & Astuti, B. (2022). Development of Cognitive Ability Test Instrument Based on Revision Bloom Taxonomy on Dynamic Electricity Materials For Students of Senior High School. *Physics Communication*, 6(2), 50–60. <https://doi.org/10.15294/physcomm.v6i2.37028>
- Pebriantika, L., Wibawa, B., & Paristiowati, M. (2021). Adoption of Mobile Learning: The Influence and Opportunities for Learning During the Covid-19 Pandemic. *International Journal of Interactive Mobile Technologies*, 15(5), 222–230. <https://doi.org/10.3991/ijim.v15i05.21067>
- Prasetyo, O., Mary, T., & Irsyadunas, I. (2024). Pengembangan Media Pembelajaran Berbasis Android Pada Mata Pelajaran Informatika Kelas X Di Smkn 4 Sijunjung. *JATI (Jurnal Mahasiswa Teknik Informatika)*, 7(5), 3469–3474. <https://doi.org/10.36040/jati.v7i5.7683>
- Puspaningsing, A. R., Tjahjardarmawan, E., & Krisdianti, N. R. (2021). *Buku IPA Kelas 10 Kurikulum Merdeka*. <https://www.scribd.com/document/623372437/Buku-Siswa-Ipa-Kelas-x-Kurikulum-Merdeka-Bukupaketcom>
- Puspitarini, Y. D., & Hanif, M. (2019). Using Learning Media to Increase Learning Motivation in Elementary School. *Anatolian Journal of Education*, 4(2), 53–60. <https://doi.org/10.29333/aje.2019.426a>
- Ramalingam, K., & Jiar, Y. K. (2022). Influence of Intrinsic and Extrinsic Motivation in Knowledge Sharing Behavior. *Central Asia And The Caucasus*,

- 23(1), 1884–1893. <https://doi.org/10.37178/ca-c.23.1.186>
- Riska, V. N., Zulva, R., & Trisna, S. (2021). Pengembangan Modul Fisika Berorientasi Model Pembelajaran Inquiry Untuk Peserta Didik. *Journal of Teaching and Learning Physics*, 6(1), 31–38. <https://doi.org/10.15575/jotalp.v6i1.10620>
- Rodemer, M., Eckhard, J., Graulich, N., & Bernholt, S. (2021). Connecting explanations to representations: benefits of highlighting techniques in tutorial videos on students' learning in organic chemistry. *International Journal of Science Education*, 43(17), 2707–2728. <https://doi.org/10.1080/09500693.2021.1985743>
- Saiye, N., & Bunga, D. A. (2024). Analisis Kesulitan Peserta Didik Dalam Memecahkan Masalah Fisika Pada Siswa Kelas Xi Sma Negeri 2 Makassar. *Jurnal Sains dan Pendidikan Fisika*, 20(3), 301–312. <https://doi.org/10.35580/JSPF.V20I3.5305>
- Sasmita, E., & Darmansyah, D. (2022). Analisis Faktor-Faktor Penyebab Kendala Guru dalam Menerapkan Kurikulum Merdeka (Studi Kasus: SDN 21 Koto Tuo, Kecamatan Baso). *Jurnal Pendidikan dan Konseling (JPDK)*, 4(6), 5545–5549. <https://doi.org/10.31004/JPDK.V4I6.9154>
- Setiani, I., Medriati, R., & Purwanto, D. A. (2024). Pengembangan Media Pembelajaran Interaktif Berbantuan Aplikasi Canva untuk Meningkatkan Pemahaman Konsep Siswa. *JoTaLP: Journal of Teaching and Learning Physics*, 9, 57–68. <https://journal.uinsgd.ac.id/index.php/jtlp/article/view/31633>
- Sidqi, M. F. K., Kurniawan, A. D., Herlina, S., & Jalal, M. A. R. (2021). Riset Kereligiousan dan Pemahaman Konsep Fisika; Studi Pendahuluan pada Kelas XI MIPA di MAN 1 Batanghari. *Departemen Pendidikan Matematika dan Pendidikan Biologi FKIP Universitas Wiralodra*, 1(1), 425–432. <https://prosiding.biounwir.ac.id/article/view/199>
- Simamora, R. (2021). Penggunaan Teknologi sebagai Inovasi Media pada Pembelajaran Fisika di Era Persaingan Industri untuk Mendukung Kampus Mengajar. *Prosiding Webinar Nasional Pendidikan Dan Sains Kimia*, 54–59. <https://conference.undana.ac.id/index.php/WNPSK/article/view/205>
- Sintawati, N. P., & Margunayasa, I. G. (2021). Interactive E-Module for Science Learning Content: Validity and Feasibility. *International Journal of Elementary Education*, 5(1), 19. <https://doi.org/10.23887/ijee.v5i1.34281>
- Siregar, H. S., & Fikri, M. (2022). Desain Media Pembelajaran Berbasis Aplikasi Android untuk Pelajaran Fiqih Materi Waris Kelas XI Madrasah Aliyah. *Gunung Djati Conference Series*, 10, 309–319. <https://www.conferences.uinsgd.ac.id/index.php/gdcs/article/view/1031>
- Sumiharsono, R., Triwahyuni, E., & Suartama, I. K. (2021). Design Considerations for Ubiquitous Learning Environment. *Turkish Journal of Computer and Mathematics Education*, 12(8), 2909–2916.
- Tatsar, M. Z., Rohman, D. C., & Salamah, U. (2022). Analisis Kemampuan Kreativitas Siswa Berbasis Proyek Energi Terbarukan Berbantuan Model Pembelajaran Project Based Learning pada Kurikulum Merdeka. *QUANTUM: Jurnal Pembelajaran IPA dan Aplikasinya*, 3(1), 23–35. <https://doi.org/10.46368/qjppia.v3i1.1105>
- Tlili, A., Shehata, B., Adarkwah, M. A., Bozkurt, A., Hickey, D. T., Huang, R., & Agyemang, B. (2023). What if the devil is my guardian angel: ChatGPT as a case study of using chatbots in education. *Smart Learning Environments*, 10(1), 15-. <https://doi.org/10.1186/s40561-023-00237-x>
- Tomlinson, C. A. (2017). How to Differentiate Instruction in Academically Diverse Classrooms. Association for Supervision & Curriculum Development. In *Ascd*. ASCD. [https://books.google.com/books/about/How\\_to\\_Differentiate\\_Instruction\\_in\\_Acad.html?hl=id&id=zoh2DgAAQBAJ](https://books.google.com/books/about/How_to_Differentiate_Instruction_in_Acad.html?hl=id&id=zoh2DgAAQBAJ)
- Windayanti, W., Afanda, M., Agustina, R., Kase, E. B. S., Safar, M., & Mokodenseho, S. (2023). Problematika Guru Dalam Menerapkan Kurikulum Merdeka. *Journal on Education*, 6(1), 2056–2063. <https://doi.org/10.31004/joe.v6i1.3197>
- Zahwa, N., Hilda, N. R., Astuti, T. K., Weryani, W., Prasetyawati, Y., Zulkardi, Z., Nuraeni, Z., & Sukmaningthias, N. (2022). Studi Literatur: Implementasi Merdeka Belajar Dalam Meningkatkan Mutu Pembelajaran Matematika Selama Pandemi. *Biomatika : Jurnal ilmiah fakultas keguruan dan ilmu pendidikan*, 8(1), 110–119. <https://doi.org/10.35569/biormatika.v8i1.1186>
- Zhai, X. (2023). ChatGPT for Next Generation Science Learning. *XRDS: Crossroads, The ACM Magazine for Students*, 29(3), 42–46. <https://doi.org/10.1145/3589649>
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