



Development of Smartphone-Based Physics Experimental Module (EFISMART)

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ABSTRACT

This study presents the development of EFISMART, a smartphone-based physics experiment module designed to enhance students' conceptual understanding through interactive and hands-on learning experiences. The primary aim is to develop an innovative and effective educational tool that integrates modern technology into physics learning to promote deeper engagement and comprehension. Employing a mixed-methods approach with an explanatory design, this research combines quantitative and qualitative data to assess both validity and effectiveness. The module underwent expert validation involving three specialists in physics, pedagogy, and language. The resulting average scores—4.32 (86.4%), 4.15 (83.0%), and 4.60 (92.0%)—indicate a "Very Valid" classification across all domains. These findings confirm that EFISMART meets scientific, pedagogical, and linguistic standards of quality. A limited trial involving 16 students demonstrated that the module effectively enhanced learner engagement, conceptual mastery, and experimental skills. Overall, EFISMART offers a contextual and technology-enhanced approach to physics education, promoting practical competence and a more meaningful understanding of scientific concepts. The module is therefore recommended for broader implementation in educational settings to support active and inquiry-based learning in science.

Keywords: EFISMART, phyphox, hands-on experiments, physics education, smartphone-based learning

INTRODUCTION

Experiments occupy a central role in physics education as they provide students with opportunities to experience physical phenomena directly, thereby deepening their conceptual understanding (Banda & Nzabahimana, 2021; Irvani et al., 2023; Rahayu et al., 2022). Through experimental activities, learners are able to connect theoretical knowledge with tangible experiences, which reinforces the concepts learned in the classroom and cultivates a more meaningful comprehension of physics principles (Ernidawati et al., 2025; Sutrio et al., 2023). Beyond strengthening conceptual understanding, experiments also serve as an essential bridge between theory and empirical validation. Engaging students in hands-on experimentation enables them to critically examine scientific theories by comparing theoretical predictions with observed results (Rahayu et al., 2022; Sutrio et al., 2023). This process not only supports the application of scientific concepts in real-life contexts (Pherson-Geyser et al., 2020) but also fosters an appreciation that physics theories are grounded in evidence derived from systematic observation and experimentation (Banda & Nzabahimana, 2021; Barari et al., 2022; Tschisgale et al., 2023).

Furthermore, experimental learning cultivates higher-order thinking and inquiry skills as students design, conduct, and analyze experiments to test theoretical assumptions (Sandberg & Alvesson, 2021). This iterative process allows learners to perceive science as a dynamic, evidence-based discipline rather than a collection of static facts. Integrating experimental activities into physics education therefore not only strengthens conceptual mastery but also nurtures scientific reasoning, practical competence, and an appreciation of the empirical foundations of scientific knowledge.

In addition to enhancing conceptual understanding, experimental activities play a critical role in developing students' scientific process skills (Alam, 2022; Husni, 2020). Through experimentation, students learn to observe systematically, collect and interpret data, and draw evidence-based conclusions. These transferable skills are valuable beyond the physics classroom, contributing to students' overall problem-solving abilities and analytical thinking. Moreover, engaging hands-on experiences stimulate students' interest and motivation in physics by providing authentic, relevant, and enjoyable learning contexts (Herwinarso et al., 2024; Pratidhina et al., 2023).

Parallel to these pedagogical advances, rapid developments in smartphone technology have significantly transformed modern education (Ikhtiyorovna, 2023; Kaputa et al., 2022). Smartphones enable instant access to diverse information sources, multimedia content, and educational applications, thereby expanding learning opportunities beyond traditional classroom boundaries. With these capabilities, teachers can design more interactive and student-centered learning environments that encourage participation and autonomy (Cueva & Inga, 2022; Irvani et al., 2020; Kilag et al., 2024).

Smartphone-based educational applications have emerged as powerful tools to support teaching and learning across disciplines (Azizah et al., 2023; Hartley & Andújar, 2022; Khasawneh et al., 2024). They offer interactive learning platforms that integrate multimedia elements, gamified features, and collaborative communication tools. These applications enhance student engagement, facilitate peer collaboration, and strengthen teacher–student interaction through accessible digital channels. The importance of smartphone integration becomes even more evident in distance learning contexts, where mobile technologies enable students to access instructional content, participate in virtual discussions, and receive continuous feedback from teachers (Irvani et al., 2025; Nurrohman, 2021; Rohman et al., 2025). In this regard, smartphones not only support flexible learning modalities but also contribute to innovative pedagogical approaches such as game-based and inquiry-oriented learning.

Within the domain of physics education, the use of experimental modules has demonstrated considerable potential in improving students' conceptual understanding and practical competence (Dessie et al., 2023; Pasaribu, 2024). Such modules enable learners to directly engage with physical phenomena, test theoretical principles, and connect abstract concepts to observable realities (Gumilar & Ismail, 2023; Liu & Fang, 2023; Mulyana et al., 2021). Integrating digital technology—particularly smartphones—into experimental modules offers educators opportunities to design more contextual, interactive, and accessible learning experiences that effectively bridge the gap between theory and practice while nurturing a deeper appreciation of scientific inquiry.

Through experimental modules, students become active participants in the learning process rather than passive recipients of information. They engage in observation, measurement, and data analysis, which facilitates a more concrete and meaningful understanding of physics concepts as they witness how these principles operate in real-world contexts (Best et al., 2025; Puspita, 2020). Moreover, such active participation helps students develop essential practical skills, including observation, data interpretation, and problem-solving (Maknun, 2020). These competencies extend beyond the physics classroom and can be applied in diverse aspects of everyday life.

The ability to apply physics concepts in solving real-world problems is a core objective of physics education (Djudin, 2023; Gumisirizah et al., 2023; Nurhuda & Irvani, 2021). Students must not only acquire theoretical knowledge but also be able to utilize it critically and creatively to address practical challenges. Experimental activities provide an effective medium for cultivating these higher-order thinking and problem-solving skills, thereby fostering scientific literacy and innovation. Building upon the pedagogical benefits of experimental modules and the growing potential of smartphone technology, smartphone-based physics experiments represent a promising alternative for technology-enhanced science learning. These tools allow students to conduct experiments more flexibly while maintaining the core principles of scientific inquiry. However, the availability of validated and pedagogically sound smartphone-based physics experimental modules remains limited. This presents a challenge for physics educators in providing learning resources that align with both scientific concepts and appropriate instructional approaches.

To address this gap, the present study focuses on the development of a smartphone-based physics experimental module named EFISMART. The module is designed to integrate technological accessibility with experimental inquiry, thereby supporting students in developing conceptual understanding, engagement, and practical skills in physics learning.

METHODOLOGY

This study employed a mixed-methods approach using an explanatory design, as proposed by Creswell and Clark (2017). The explanatory design combines quantitative (QUAN) and qualitative (qual) research methods sequentially, with the quantitative phase serving as the primary component and the qualitative phase used to elaborate and interpret the quantitative findings. This approach enables a comprehensive understanding of the effectiveness and validity of the developed product by integrating numerical data with in-depth descriptive insights. The research process began with the development of the EFISMART module using the 3D+E model, which comprises four key stages: Define, Design, Develop, and Evaluate. The 3D+E model is a modification of the classic 4D model—Define, Design, Develop, and Disseminate which was introduced by Thiagarajan (1974). In this adaptation, the Disseminate stage is replaced by Evaluate to emphasize systematic assessment rather than broad distribution. The model provides a structured framework to guide the design, validation, and refinement of the instructional product. An overview of the EFISMART module development process based on the 3D+E model is presented in Figure 1, which illustrates the sequence of activities undertaken in each phase, from needs analysis and design formulation to product testing and evaluation.

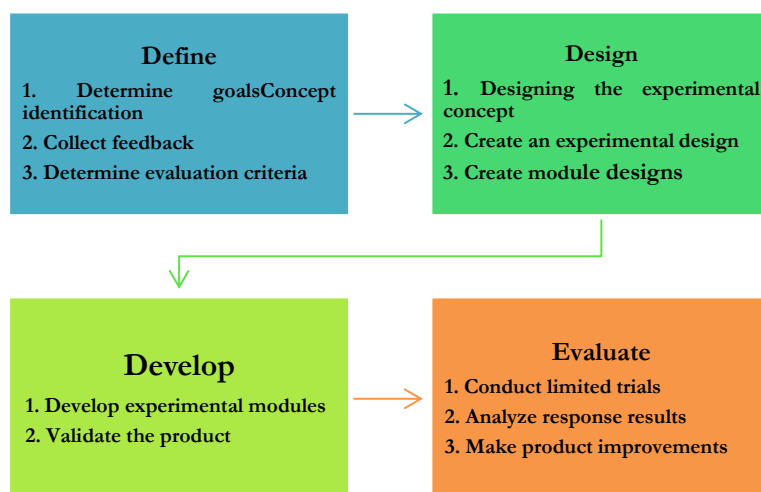


Figure 1. 3D+E Development Model for Developing EFISMART Module

During the development stage, the product underwent a validation process involving three expert reviewers. The validators were purposefully selected based on their expertise in physics content, digital learning, and learning assessment, ensuring a comprehensive evaluation of the module's scientific accuracy, technological relevance, and instructional quality. Their involvement was not limited to language and pedagogical aspects but extended to assessing the alignment between physics concepts and their digital representation within the module. Each expert possessed substantial experience in the field of physics education, which guaranteed that the validation process reflected both disciplinary depth and pedagogical soundness. Feedback and recommendations provided by these experts were systematically analyzed and incorporated to enhance the overall quality of the EFISMART module prior to proceeding to the evaluation stage.

Research Subject

During the evaluation phase, the EFISMART module was tested on a limited scale involving 16 students and one lecturer from the Physics Education program. The participants were undergraduate students enrolled in the Basic Physics Experiment course, comprising nine females and seven males. All participants had previously completed courses in General Physics and Basic Physics, ensuring the necessary foundational knowledge to effectively engage with the developed module. The inclusion of 16 students and one lecturer was intentionally designed to conduct a preliminary trial, aimed at collecting initial feedback and identifying potential areas for improvement prior to broader implementation. This limited sample was considered adequate to represent prospective users and to evaluate the practicality and usability of the product in a controlled learning setting. Both the lecturer and the students were asked to complete structured questionnaires to provide responses and qualitative feedback on their experiences with the EFISMART module, which were subsequently analyzed to inform further product refinement.

Data Analysis Techniques

The data obtained from expert validation were analyzed quantitatively by calculating the mean scores and converting them into percentage values to determine the validity level of the developed module. The resulting percentages were then interpreted according to predetermined validity criteria, categorized as very valid, valid, fairly valid, or less valid. In parallel, the data collected from student and lecturer questionnaires were analyzed descriptively to assess the module's practicality and attractiveness in classroom use. Furthermore, qualitative feedback and suggestions from both validators and respondents were subjected to thematic analysis to identify recurring patterns, highlight areas for improvement, and guide the refinement of the EFISMART module prior to wider implementation.

RESULT AND DISCUSSION

The Define stage

The Define stage serves as a critical initial phase in the development of the smartphone-based physics experimental module. At this stage, a series of systematic analyses are conducted to ensure that the designed module aligns with user needs, curriculum requirements, and intended learning outcomes. The purpose of this stage is to establish a clear foundation for the subsequent design and development processes, ensuring that the final product effectively addresses educational challenges and supports meaningful learning experiences.

The main activities undertaken in this stage involved a comprehensive series of analyses and consultations to ensure that the developed module met the identified educational and technical needs. The process began with a material needs analysis, which aimed to identify essential physics

concepts to be included in the module through a review of relevant literature and curriculum documents. This analysis highlighted topics that are often challenging for students, such as Newton's laws, harmonic motion, and energy concepts, thereby guiding the development team in prioritizing materials requiring deeper conceptual reinforcement (Putri et al., 2020). Subsequently, an analysis of smartphone sensor availability was conducted to examine the types of sensors commonly found in students' smartphones, such as accelerometers, gyroscopes, and light sensors, which can be utilized as data collection tools in physics experiments. This evaluation ensured that the designed module would be compatible with students' existing devices, promoting accessibility and practicality. Furthermore, an analysis of the Phyphox application was carried out, as it was identified as an appropriate platform for smartphone-based physics experimentation (Imtinan & Kuswanto, 2023; Sriyansyah & Anwar, 2021). The development team examined key features of the application, including data recording, graphical analysis, and experimental parameter settings, to assess its pedagogical and technical potential. The findings from this analysis informed the module's design, enabling the integration of Phyphox features to facilitate interactive and engaging experimentation. In addition, an analysis of the learning outcomes outlined in the Basic Physics Experiment course curriculum was performed to ensure that the module aligns with institutional competency standards, particularly in fostering analytical reasoning, problem-solving abilities, and practical applications of physics concepts. To further strengthen the module's relevance, consultations were conducted with key stakeholders, including lecturers and students who had previously completed the physics experiment course. Through interviews and focus group discussions, valuable insights were gathered regarding common challenges and preferred module features, which were then used to refine the content and enhance usability. Finally, all outcomes from the Define stage—including the results of the material analysis, sensor evaluation, Phyphox feature analysis, and learning outcomes alignment—were systematically documented. This documentation serves as a foundational reference for subsequent development stages, ensuring that the design process remains consistent with the findings of the analysis phase.

The Design Stage

The Design stage represents the second phase in developing the smartphone-based physics experiment module. In this phase, the development team translates the analytical results from the Define stage into a concrete design plan, outlining the structure, learning content, and instructional features of the module.

The main activities in this stage encompassed several interconnected processes aimed at developing a coherent, engaging, and pedagogically effective module. The first activity involved the development of the module framework, which served as the foundation for the overall design process. At this stage, the development team formulated the basic structure of the module to ensure that each component contributed to a coherent and systematic learning flow (Elouny et al., 2020). The framework consisted of essential elements such as a descriptive module title, an introductory section outlining learning objectives and relevance, a table of contents for ease of navigation, and a main body comprising theoretical materials, practical guides, assessments, and references. This organization was designed to create a logical, user-friendly progression of learning that supports students in understanding and applying physics concepts effectively.

Subsequently, the design of the learning content was carried out as a pivotal stage in the module development process. The learning content was systematically structured to meet the needs and characteristics of prospective physics teachers, particularly in mastering complex and abstract concepts. In this process, challenging topics such as atomic electronic structure were presented through analogy-based explanations to enhance conceptual clarity and accessibility. Each section integrated explanatory texts, visual aids, relevant examples, and formative exercises that reinforced students' understanding. Moreover, the content supported self-paced learning, enabling students

to study individually or collaboratively, thereby strengthening their analytical and conceptual reasoning skills.

The next stage focused on the development of practical activities, which played a crucial role in bridging theoretical understanding with real-world applications. In this step, the development team designed experiments utilizing smartphone sensors and the Phyphox application to explore various physics phenomena. Each practical activity included detailed experimental procedures, lists of required tools and materials, and step-by-step guidance to ensure feasibility and clarity. These experiments were intentionally designed to foster inquiry, exploration, and problem-solving, encouraging students to engage actively in the learning process. Through these activities, students were expected to deepen their conceptual understanding and develop essential scientific process skills relevant to physics education.

Furthermore, the preparation of module usage guidelines was undertaken to ensure effective navigation and implementation by users, particularly prospective physics teachers (Rosdiana et al., 2019). The guidelines provided detailed instructions on how to utilize each component of the module, conduct experiments, and interpret experimental data. They also included strategies for addressing potential learning difficulties and guidance on using the provided exercises and assessments to evaluate learning outcomes. These comprehensive instructions aimed to promote learner autonomy, enhance confidence in conducting experiments, and create a supportive environment that facilitates meaningful learning experiences.

Finally, the module's visual design was carefully developed as an essential element influencing user engagement and comprehension. Attention was given to color schemes, typography, and layout to ensure visual harmony and readability. Illustrations, diagrams, and contextually relevant images were incorporated to help visualize abstract physics concepts and make the learning experience more interactive. The design emphasized clarity, balanced spacing, and consistency in visual elements to prevent cognitive overload while maintaining aesthetic appeal. This visual approach was intended to strengthen students' cognitive engagement and contribute to a more enjoyable and effective learning experience.

The Develop Stage

At this stage, the smartphone-based physics experimental module is developed in accordance with the framework and design specifications established during the previous phase. The development process focuses on producing a learning module that is both pedagogically effective and technologically accessible for students. After the initial prototype is completed, the module undergoes expert validation involving three specialists: a physics content expert, a digital media expert, and a language expert. The physics content expert is a senior lecturer in the Physics program at a university in Bandung, responsible for evaluating the scientific accuracy and conceptual alignment of the materials. The media expert, a lecturer in Physics Education at a public university in Tasikmalaya, assesses the module's technological design, interactivity, and usability. Meanwhile, the language expert, a senior lecturer in the Indonesian Language course at a university in Garut, reviews the linguistic clarity, readability, and communicative appropriateness of the text.

This validation process aims to ensure that the developed module is not only scientifically accurate and pedagogically sound but also engaging, linguistically accessible, and easy for students to understand. Feedback from the experts serves as the basis for revising and refining the module prior to its implementation in the subsequent evaluation phase. The resulting version of the developed module is illustrated in Figure 1.



Figure 1. Display of the Smartphone-Based Physics Experiment Module (EFISMART)

After the development of the module was completed, a construct validation process was carried out by involving three experts to ensure the accuracy, clarity, and pedagogical appropriateness of the product. As outlined in the methodology section, the experts comprised a content expert, a pedagogy expert, and a language expert. Each expert provided assessments based on their respective areas of specialization to evaluate the quality and validity of the module from different perspectives. The content expert focused on the scientific accuracy and conceptual consistency of the material, the pedagogy expert evaluated the instructional design and learning effectiveness, while the language expert examined the linguistic clarity and readability of the text. The outcomes of this expert validation process are summarized in Table 1, Table 2, and Table 3, which present the quantitative results and corresponding qualitative feedback used to refine the final version of the module.

Table 1. Physics Content Experts Validation Results

Average scores	Criteria	Interpretation
4.32	86.4%	Very Valid

The results of the validation conducted by physics content experts indicate that the smartphone-based physics experiment module (EFISMART) achieved an average score of 4.32, corresponding to a validity percentage of 86.4%, which falls within the “Very Valid” category. This outcome demonstrates that the developed module is scientifically accurate and aligns with the conceptual and pedagogical standards expected in physics education. The high validation score signifies that the module content is both relevant and consistent with established physics principles, thereby ensuring that it effectively supports students’ conceptual understanding. These findings affirm that the EFISMART module is appropriate for classroom implementation, as it meets expert expectations in terms of accuracy, coherence, and depth of physics content. Consequently, the module is expected to contribute positively to the learning process by providing students with scientifically sound material that promotes meaningful understanding of physical concepts (Lina & Desnita, 2022).

Table 2. Pedagogy Expert Validation Results

Average scores	Criteria	Interpretation
4.15	83.0%	Very Valid

The results of the pedagogical expert validation indicate that the smartphone-based physics experiment module (EFISMART) achieved an average score of 4.15, equivalent to a validity percentage of 83.0%, which is categorized as “Very Valid.” This finding demonstrates that the module not only fulfills the academic requirements of physics content but also effectively incorporates sound pedagogical principles. The high validation score suggests that the module is appropriately structured to facilitate active learning and enhance students’ conceptual understanding through guided experimentation. Moreover, the pedagogical design of EFISMART ensures that learning activities are student-centered, interactive, and aligned with modern instructional strategies that promote engagement and inquiry-based learning. Validation from pedagogical experts is essential in confirming that the instructional framework embedded in the module supports both meaningful learning experiences and improved student participation during experimental activities (Adams & Du Preez, 2022).

Table 3. Language Expert Validation Results

Average scores	Criteria	Interpretation
4.60	92.0%	Very Valid

The results of the language expert validation indicate that the smartphone-based physics experiment module (EFISMART) obtained an average score of 4.60, corresponding to a validity percentage of 92.0%, which is classified as “Very Valid.” This result demonstrates that the EFISMART module not only achieves high standards in terms of scientific accuracy and pedagogical design but also excels in linguistic quality. The high validation score reflects that the language used in the module is clear, concise, and easily comprehensible to students. Furthermore, the module’s language adheres to proper grammatical and structural conventions, ensuring that instructions, explanations, and discussions are communicated effectively. Validation from language experts is crucial to guarantee that the instructional materials are linguistically accessible to learners, thereby facilitating comprehension and fostering a more engaging and effective learning experience (Bin-Tahir et al., 2020).

The Evaluate Stage

The Evaluate stage represents a critical phase in the development process of the smartphone-based physics experiment module (EFISMART), as it serves to assess the effectiveness, practicality, and overall quality of the developed product. At this stage, the module was subjected to limited-scale testing involving a group of undergraduate students from the Physics Education program. The evaluation process comprised four key activities: (1) conducting limited trials, (2) administering response questionnaires, (3) analyzing student and lecturer feedback, and (4) implementing necessary product revisions. The limited trial was carried out with 16 students who were enrolled in the Physics Education program and had prior experience with foundational physics courses. This group was selected to represent the target users of the module and to provide meaningful insights into its usability and instructional effectiveness. The data obtained from the questionnaire responses were analyzed to assess the students’ perceptions of the clarity, interactivity, and relevance of the EFISMART module. The summarized results of these responses are presented in Table 4, which provides an overview of students’ evaluations regarding the practicality and appeal of the developed learning module.

Table 4. Results of Trial to Students

Aspect	Eligibility Score	
	Average	Criteria
Content	3.21	Very Eligible
Curiosity	3.35	Very Eligible
Attractiveness	3.26	Very Eligible
Mastery	3.44	Very Eligible
Presentation	3.62	Very Eligible
Average	3.38	Very Eligible

Table 4 presents the findings from the limited trial of the smartphone-based physics experiment module (EFISMART) conducted with a group of students in the Physics Education program. The trial assessed several key dimensions of the module, including content quality, presentation clarity, attractiveness, and its ability to foster curiosity and conceptual mastery. The analysis yielded an average score of 3.21, which corresponds to the category of “Very Eligible.” This result indicates that the EFISMART module not only meets academic and pedagogical standards but also aligns well with students’ expectations as an engaging and effective learning tool.

The consistently high ratings across all evaluated aspects highlight the module’s strong potential to support and enhance the physics learning process. Students reported that the module was interactive, accessible, and stimulating, effectively bridging the gap between theoretical concepts and their practical applications. The integration of smartphone sensors through the Phyphox application enabled students to conduct real-time experiments, thereby transforming abstract physics principles into tangible, observable phenomena. Moreover, the “Very Eligible” classification underscores the module’s capability to address persistent challenges in conventional physics instruction, such as limited access to laboratory equipment and difficulties in visualizing abstract concepts. By leveraging the ubiquitous nature of smartphone technology, EFISMART democratizes access to experimental learning opportunities, allowing students to explore and validate physical principles independently and contextually.

These findings affirm that the EFISMART module effectively fulfills students’ learning needs by providing a modern, practical, and interactive approach to physics education. Its integration into the curriculum has the potential to significantly improve students’ engagement, conceptual comprehension, and essential scientific competencies such as observation, data analysis, and critical thinking (Czaplinski & Fielding, 2020). Nevertheless, this study acknowledges a limitation in sample size—involving only 16 students and one lecturer—which constrains the generalizability of the findings (Etz & Arroyo, 2015). Therefore, it is recommended that future research involve a larger and more diverse participant group, including additional lecturers or laboratory assistants, to strengthen the robustness and applicability of the results while maintaining feasible implementation conditions.

Limitations of the Study

This study acknowledges several limitations that should be taken into consideration. First, the sample size was relatively small, involving only 16 students and one lecturer, which may limit the generalizability of the findings. The results obtained from this limited trial may not fully represent the characteristics or experiences of a broader student population; therefore, further validation is required with a larger and more diverse sample. Second, the scope of this study was confined to the implementation of a smartphone-based module within a single basic physics experiment course. Consequently, the module’s effectiveness in other physics courses or within different educational contexts remains unexplored. These limitations indicate the necessity for future research to extend the evaluation of EFISMART by involving more participants, diverse

academic settings, and varying levels of instructional complexity. Broader investigations will help determine the scalability, adaptability, and long-term impact of the module across multiple learning environments and subject domains.

Future Research Directions

Future research will focus on the further testing and refinement of the EFISMART module to extend its applicability within a broader context of physics education. Upcoming studies will involve a larger and more diverse sample, encompassing students from various programs and educational institutions, to comprehensively evaluate the module's effectiveness across different academic settings. In addition, the module will be expanded to cover a wider range of physics topics beyond basic experiments and adapted for different educational levels, including senior high school and higher education. Further development will also explore the integration of EFISMART with other digital learning tools, aiming to create a more collaborative, project-based, and interactive learning environment. Through these advancements, it is expected that EFISMART will become a versatile digital learning innovation capable of enhancing student engagement, conceptual understanding, and scientific inquiry skills across diverse educational contexts.

CONCLUSION

The development of the smartphone-based physics experiment module (EFISMART) using the Phyx application and the 3D+E development model demonstrates substantial potential to enhance the quality of physics education. The module has undergone a comprehensive validation process involving three expert domains—content, pedagogy, and language—with all evaluations indicating a very high level of validity. These results suggest that EFISMART not only meets academic and scientific standards but also effectively integrates modern digital technology to create a more interactive, engaging, and student-centered learning experience. The module's ability to facilitate real-time experimentation through smartphones makes it a practical and innovative alternative for institutions facing limited laboratory resources. It is therefore expected that the EFISMART module can be widely implemented in physics education curricula across various educational institutions, contributing to the improvement of students' conceptual understanding, practical skills, and scientific inquiry abilities.

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