

Needs Analysis for the Development of Phyphox-Based Mobile Learning in Physics Education at Vocational High Schools

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Abstract: This study aims to analyze the learning needs of 10th-grade students at SMKN 1 Prabumulih regarding physics measurement topics and to assess their readiness and acceptance of Phyphox-based mobile learning for developing Science Process Skills (SPS). A quantitative descriptive approach was employed, with data collected through a 15-item needs analysis questionnaire distributed online via Google Forms to 109 students from four vocational programs. The questionnaire covered smartphone ownership, perceptions of physics learning, learning barriers, laboratory frequency, technology acceptance, and SPS-based mobile learning feature needs. Results indicate that 99.10% of students own a personal smartphone and 90.80% are permitted to use it for learning. Although 98.20% of students (71.60% rarely and 26.60% never) did not receive adequate laboratory experience, 61.50% believed hands-on experiments were the most effective learning method. Technology acceptance reached 92.70% despite 94.50% having never used Phyphox. Additionally, 75.2% strongly needed SPS-based self-directed learning materials, and 52.30% desired comprehensive features integrating step-by-step guides, real-time data displays, and interactive interfaces. These findings confirm that Phyphox-based mobile learning is technically feasible, pedagogically necessary given documented deficits in students' SPS, and socially acceptable, providing a strong empirical foundation for the development of PhysicsLab mobile learning in vocational physics education.

Keywords: Mobile learning; Needs analysis; Physics lab; Science process skills

Introduction

Physics is a branch of natural science built upon observation, measurement, experimentation, and scientific reasoning (Amalishsholeh et al., 2023). The topics of measurement and physical quantities form the core foundation of physics education because they are directly related to the skills of using measuring instruments, reading data, and scientifically analyzing measurement results (Angraini et al., 2024). Therefore, physics education emphasizes not only conceptual understanding but also the development of Science Process Skills (SPS), which include the ability to observe, measure, formulate hypotheses, conduct experiments, analyze data, and draw conclusions (Kurniawati, 2021; Mahmudah et al., 2022; Nurfausiah et

al., 2025). SPS is an important competency that supports students' critical thinking and problem-solving skills and therefore needs to be developed to the fullest extent possible in physics instruction.

Practical laboratory activities are an important component of physics education, yet their implementation in Sekolah Menengah Kejuruan (SMK) still faces various challenges. Limited laboratory facilities, restricted class time, and the predominance of teacher-centered teaching methods result in students primarily gaining theoretical learning experiences (Melnix et al., 2024). These conditions contribute to students' low science process skills and reduce opportunities for authentic scientific investigation, particularly in schools with limited laboratory facilities

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(Raharja et al., 2025; Rophi et al., 2024; Setyaningrum et al., 2025).

Advances in digital technology, particularly smartphones, have opened up opportunities to overcome these limitations through mobile learning. One application that supports smartphone-based physics experiments is Phyphox (Physical Phone Experiments), developed by RWTH Aachen University, which enables the real-time use of smartphone sensors (Staacks et al., 2022). Similar smartphone-based experimental approaches have also been successfully implemented in university-level physics courses to replace conventional exercises with sensor-based measurements (Kaps et al., 2021). By transforming smartphones into portable laboratories, Phyphox allows students to conduct experiments more flexibly, both inside and outside conventional laboratories (Kuhn et al., 2013). Growing evidence suggests that integrating Phyphox into mobile learning positively influences physics education. For instance, Evains et al. (2024) reported that the use of Phyphox improved students' science process skills (SPS), with an average score of 72.08. These findings are consistent with recent studies reporting that technology-based instructional materials improve students' engagement, accessibility, and independent learning in physics (Ayani et al., 2025; Siswanto et al., 2025). Likewise, smartphone sensor based experiments have been shown to improve students' motivation and learning outcomes, particularly in measurement-related topics (Irvani et al., 2023).

However, research specifically analyzing the needs of vocational high school students regarding the development of Phyphox-based mobile learning to train SPS in the subject of measurement and physical quantities remains very limited. While Evains et al. (2024) and Syah et al. (2025) demonstrated the benefits of Phyphox in general high school (SMA) settings, no study has yet specifically examined its application in Indonesian vocational high schools (SMK), where students have distinct learning characteristics and career-oriented curricula. Vocational education plays a critical role in skill formation and long-term social and economic development, making the integration of practical, technology-supported learning particularly urgent in this context (Pan et al., 2025). This gap is significant because SMK students require practical, hands-on learning experiences that are directly relevant to their vocational competencies, yet are consistently underserved by conventional laboratory-based instruction. The novelty of this study lies in its focus on SMK students as a distinct population, providing the first empirical needs analysis for the development of Phyphox-based mobile learning specifically tailored to the vocational education context in Indonesia.

In fact, needs analysis is a crucial initial stage in the 4D development model to ensure that the product developed aligns with user characteristics (Melnix et al., 2024; Thiagarajan et al., 1974). Therefore, this study aims to analyze the learning needs of vocational high school students in physics regarding measurement and physical quantities, as well as to examine their readiness and acceptance of Phyphox-based mobile learning for developing Science Process Skills. The results of this study are expected to serve as an empirical foundation for the development of Phyphox-based PhysicsLab mobile learning that meets the needs and characteristics of vocational high school students.

Method

This study employs a quantitative descriptive approach as part of the Define phase in the 4D instructional development model Define, Design, Develop, Disseminate (Thiagarajan et al., 1974). The 4D model has been widely applied in developing physics learning materials in the Indonesian vocational and secondary education context, demonstrating its suitability as a systematic framework for developing contextually relevant instructional products (Pratiwi et al., 2025; Wiyono et al., 2025). A quantitative descriptive method was chosen to systematically describe, summarize, and interpret the numerical data from the research sample (Creswell, 2018). Data were collected using a 15-item needs analysis questionnaire administered online through Google Forms to 109 tenth-grade students at SMKN 1 Prabumulih.

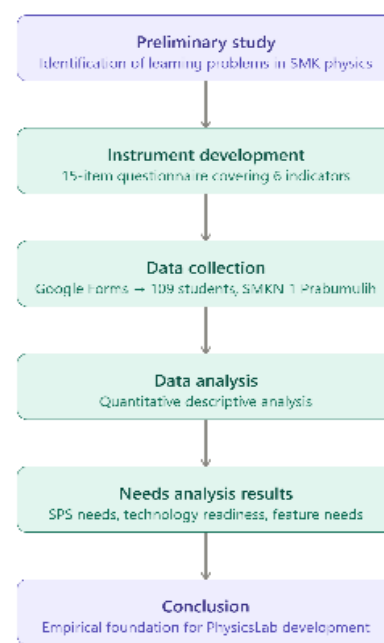


Figure 1. Research procedure flowchart

The sample was selected using purposive sampling and comprised students from four vocational programs: Accounting (AK), Motorcycle Engineering (TSM), Light Vehicle Engineering (BR), and Electrical Installation Engineering (TITL). The research procedure is presented in Figure 1. It began with a preliminary study to identify problems in physics learning, followed by the development of a needs analysis instrument based on six indicators. The questionnaire responses were analyzed using descriptive statistics, including frequencies and percentages. The findings were then interpreted according to each indicator to identify students' learning needs, learning barriers, technology readiness, and expectations toward Phyphox-assisted PhysicsLab

mobile learning. These results served as the empirical basis for the Define phase of the 4D development model.

The research instrument consisted of 15 questions covering six main indicators, namely smartphone ownership and usage patterns, perceptions of physics learning, main barriers to learning measurement and physical quantities, frequency of lab activities and experiment preferences, experience using Phyphox and acceptance of technology, and needs for mobile learning features and Science Process Skills (SPS). The instrument was validated through expert judgment to ensure content suitability, and all items were confirmed appropriate for the needs analysis purpose. The instrument's item list is presented in Table 1.

Table 1. Specification for Needs Analysis Questions

Key Indicator	Sub-Indicator	Response Type	Item No.	Number of Items
Smartphone Ownership & Usage	Ownership of personal smartphones; school permission to use smartphones in learning; daily usage duration	Yes/No; Multiple Choice	1-3	3
Perceptions of Physics Learning	Students' Attitudes About Physics	Multiple Choice	4	1
Challenges with Measurement Materials	Too much theory/formulas; not enough lab work; limited lab equipment; not relevant to everyday life	Multiple Choice	5-8	4
Practicum Frequency & Experiment Preferences	Frequency of lab sessions; preference for hands-on experiments as a learning method	Multiple Choice	9-10	2
Phyphox Experience & Technology Adoption	Previous use of the Phyphox app; approval of smartphones as digital measuring devices	Yes/No; Likert scale	11-12	2
Mobile Learning Feature Requirements & SPS	Desired mobile learning features (step-by-step guides, real-time data, interactive UI); SPS-based media requirements for self-directed learning	Multiple Choice	13-15	3

Result and Discussion

A requirements analysis was conducted during the Define phase of the PhysicsLab mobile learning development. The analysis aimed to identify students' learning needs, challenges in learning quantities and measurement, technology readiness, and expectations regarding mobile learning to support science process skills. Data were collected using a Google Forms questionnaire administered to 109 tenth-grade students from four vocational programs at SMKN 1 Prabumulih. Conducting a needs analysis at the initial stage of educational product development helps ensure that the

developed learning media aligns with learners' needs and instructional contexts (Aji et al., 2025; Rahayu et al., 2025). The distribution of participants across the vocational programs is presented in Table 2.

The questionnaire used in this study consisted of 15 items developed based on indicators of physics learning needs and technology readiness. The instrument was designed through a literature review and aligned with the research objectives to identify students' needs as the basis for developing the Phyphox-assisted PhysicsLab mobile learning platform. The results of the needs analysis are presented according to the main indicators below.

Table 2. Distribution of Research Respondents by Vocational Program

Specialization Program	Class	Number of Student
Accounting (AK)	X AK 2	34
Motorcycle Engineerign (TSM)	X TSM	29
Light Vehicle Engineering (BR)	X BR	26
Electrical Installation Engineering (TITL)	X TITL 1 & 2	20

Smartphone Ownership and Technology Infrastructure

The first indicator examined students' access to smartphones and their readiness to adopt mobile technology for physics learning. As shown in Figure 2, 99.10% of students owned a personal smartphone, 90.80% were permitted to use smartphones during learning activities, and 54.10% used their smartphones for two to five hours daily. These findings indicate that smartphones are already an integral part of students' daily lives, providing a strong technological foundation for implementing mobile-learning.

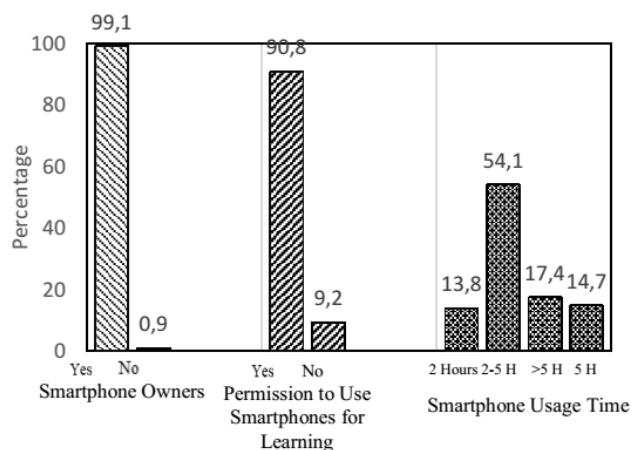


Figure 2. Smartphone ownership and technology infrastructure

The high level of smartphone ownership demonstrates that mobile learning can be implemented with minimal technological barriers. This finding is consistent with Pardede et al. (2025), who reported that smartphone ownership among Indonesian senior high school students exceeded 96.00%, indicating that mobile devices have become widely accessible even in developing regions. Similarly, Pratama et al. (2020) emphasized that device ownership and adequate technological infrastructure are fundamental prerequisites for successful mobile learning implementation. Therefore, the availability of smartphones among students at SMKN 1 Prabumulih provides a strong foundation for integrating smartphone-assisted physics learning into classroom practice. Beyond device ownership, institutional support also plays a crucial role in determining the feasibility of technology-enhanced learning. The finding that 90.80% of students were allowed to use smartphones during lessons reflects a positive institutional attitude toward educational technology, Rahman et al. (2025) and Arini et al. (2025), identified supportive school policies as one of the strongest determinants of successful mobile learning implementation in vocational education. Such policies not only facilitate technology integration but also

encourage teachers to adopt more innovative instructional approaches. The relatively intensive daily smartphone usage further suggests that students are already familiar with mobile technology, reducing the learning curve associated with introducing new educational applications. Rather than serving merely as communication devices, smartphones can be transformed into portable scientific laboratories through applications such as Phyphox. Staacks et al. (2022) demonstrated that smartphone sensors are capable of supporting various real-time physics experiments with sufficient accuracy for educational purposes. Therefore, the combination of widespread smartphone ownership, supportive institutional policies, and students' familiarity with mobile technology indicates that the implementation of Phyphox-based PhysicsLab mobile learning is technically feasible and highly relevant to the vocational education context.

Perceptions of Physics Learning

Students' perceptions of physics learning are important because positive attitudes are closely associated with motivation, engagement, and learning achievement. The questionnaire results revealed that 54.10% of students considered physics enjoyable, whereas 42.20% perceived it as moderately interesting, and only 3.70% regarded it as difficult or uninteresting. These findings indicate that most students already possess a favorable attitude toward physics, although a considerable proportion remains insufficiently engaged. The large proportion of students expressing neutral perceptions deserves particular attention. Rather than indicating a negative attitude, this finding suggests that existing instructional practices have not yet fully connected physics concepts with students' vocational interests and everyday experiences. Vocational high school students generally expect learning activities to be practical, contextual, and directly related to their future careers. Consequently, conventional teacher-centered instruction may not adequately satisfy these expectations.

This interpretation is supported by Astalini et al. (2019) and Aprianti et al. (2024) emphasize that students' motivation and learning outcomes in physics are significantly shaped by the perceived relevance of learning activities to real world applications. In the vocational context, this relevance is especially critical, SMK students are oriented toward specific career competencies, and physics instruction that fails to connect with their vocational interests risks being perceived as abstract and irrelevant. Technology-supported learning environments offer opportunities to transform these neutral perceptions into active engagement, Sulastris et al. (2024) demonstrated that digital learning media integrated with Project-Based

Learning enhanced students' motivation, participation, and conceptual understanding. In the present study, these findings imply that Phyphox-based PhysicsLab should not merely function as a digital learning platform but should also provide authentic experimental activities that relate physics concepts to vocational applications. Such contextual experiences may increase students' interest while simultaneously promoting the development of Science Process Skills (SPS).

The Main Challenges in Learning

The needs analysis identified several major obstacles encountered by students when learning measurement and physical quantities. As presented in Table 3, the most frequently reported challenges were an excessive emphasis on theoretical explanations and formulas (55.00%) and insufficient opportunities for laboratory activities (53.20%). Other important barriers included limited laboratory equipment (31.20%) and the perceived lack of relevance between physics concepts and everyday life (17.40%). Since respondents were allowed to select multiple answers, these percentages represent students' perceptions of different learning barriers rather than mutually exclusive categories.

Table 3. The Learning Barriers Reported by Students

Factors	f	%
There are too many theories and formulas	60	55.00%
Lack of practical work/experiments	58	53.20%
Limited laboratory equipment	34	31.20%
The material is not relevant to everyday life	19	17.40%

*Note: Students may select more than one option

The predominance of theory-oriented instruction suggests that students have limited opportunities to experience scientific inquiry through direct experimentation. Physics concepts become more meaningful when students actively observe phenomena, perform measurements, analyze data, and draw conclusions (Pramitasari et al., 2024). However, the findings indicate that instructional practices remain largely dominated by theoretical explanations, reducing opportunities to develop practical scientific competencies.

These findings are consistent with Amalissholeh et al. (2023), who reported that students commonly perceive physics as difficult because instruction focuses heavily on mathematical formulas while providing insufficient experimental experiences. Similarly, Chengere (2025) concluded that inadequate laboratory facilities substantially limit the development of students' Science Process Skills, particularly observation, measurement, and data interpretation. Muzammal et al. (2025) further demonstrated that limited laboratory infrastructure restricts students' opportunities to

participate in meaningful experimental activities, thereby negatively affecting practical competence. Importantly, the identified learning barriers should not be interpreted independently because they are closely interconnected. The dominance of theoretical instruction, scarcity of laboratory activities, and limited laboratory facilities collectively reduce opportunities for students to develop Science Process Skills through authentic investigations. This situation is particularly problematic in vocational education, where practical competence constitutes a central learning objective. Consequently, alternative learning media capable of facilitating experimental activities beyond conventional laboratories are urgently needed.

Phyphox-based PhysicsLab provides a promising solution to these challenges by transforming students' smartphones into portable scientific instruments. Through smartphone sensors, students can perform experiments, collect real-time data, and analyze measurement results without depending entirely on conventional laboratory equipment. Previous studies by Imtinan et al. (2023) and Laeli et al. (2023) demonstrated that Phyphox effectively supports various physics experiments while increasing students' opportunities to engage in scientific investigation. Therefore, integrating Phyphox into mobile learning has the potential not only to overcome laboratory limitations but also to create more authentic, inquiry-oriented learning experiences that strengthen students' Science Process Skills.

Practicum Frequency and Experiment Preferences

The findings regarding laboratory participation reveal a substantial gap between students' preferred learning experiences and the instructional practices currently implemented in physics classrooms. As illustrated in Figure 3, 71.60% of students reported that they rarely participated in laboratory activities, while 26.60% indicated that they had never conducted a physics experiment. Consequently, 98.20% of students experienced either limited or no practical laboratory activities throughout their learning process. It should be noted that this percentage represents the combined proportion of students who selected "rarely" and "never," whereas the percentages presented in Table 3 refer to students' perceptions of learning barriers, where multiple responses were permitted. Therefore, the two datasets complement rather than contradict one another.

Despite the limited availability of laboratory activities, 61.50% of students identified hands-on experiments as the most effective approach for learning physics. This discrepancy indicates that students recognize the educational value of experimentation but have limited opportunities to experience inquiry-based learning in practice. Such conditions may hinder the development of Science Process Skills (SPS), as these

skills require repeated engagement in observation, measurement, experimentation, data analysis, and scientific reasoning. These findings are consistent with Arifin et al. (2023) who reported that inadequate laboratory facilities and limited instructional time remain major obstacles to practical physics instruction in Indonesian schools. Likewise, Subekti et al. (2016) demonstrated that experimental learning significantly improves both conceptual understanding and Science Process Skills compared with conventional lecture-based instruction. Sinuraya et al. (2023) further emphasized that SPS cannot be developed solely through theoretical instruction but require authentic scientific investigations that actively involve students in the inquiry process. The present findings also suggest that laboratory limitations should not be viewed merely as infrastructure problems but as pedagogical challenges. Students who rarely participate in practical activities are less likely to acquire the procedural competencies necessary for vocational education, where technical and practical abilities are equally important as conceptual knowledge. Consequently, the absence of laboratory experiences may reduce students' readiness for future workplace demands.

Recent developments in smartphone sensor technology offer a practical alternative to conventional laboratory instruction. Kuhn and Vogt (2013) demonstrated that smartphones can accurately perform various physics measurements, allowing students to conduct experiments using devices already available in their daily lives. Similarly, Imtinan and Kuswanto (2023) concluded that Phyphox has been successfully implemented across numerous physics experiments and consistently enhances students' engagement in scientific inquiry. Laeli et al. (2023) also confirmed that Phyphox provides reliable experimental measurements comparable to conventional laboratory equipment. Therefore, integrating Phyphox into PhysicsLab mobile learning represents a practical strategy for expanding laboratory opportunities while simultaneously fostering students' Science Process Skills in vocational education.

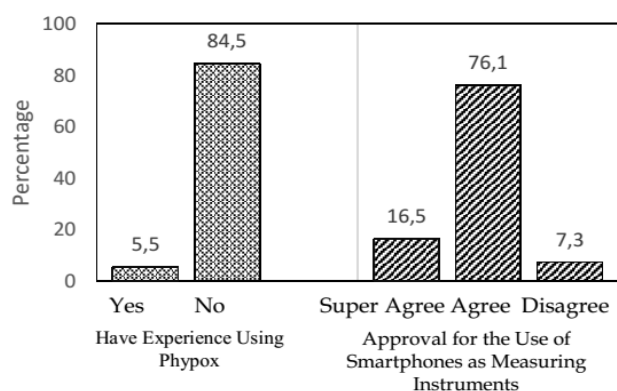


Figure 3. Adoption of phyphox-based mobile learning technology

The Phyphox Experience and Technology Acceptance

Students' prior experience with educational technology and their willingness to adopt new digital tools were examined to determine the feasibility of implementing Phyphox-based mobile learning. As presented in Figure 4, 94.50% of students had never previously used the Phyphox application. Nevertheless, technology acceptance was remarkably high, with 92.70% of respondents agreeing or strongly agreeing that smartphones could function as scientific measuring instruments during physics learning. Only a small proportion of students expressed uncertainty or disagreement regarding its implementation. This finding demonstrates that prior experience with a particular technology is not necessarily a prerequisite for successful technology adoption. Instead, students appear willing to embrace innovative learning tools when they perceive clear educational benefits and practical relevance. This interpretation aligns with the Technology Acceptance Model, which suggests that perceived usefulness and perceived ease of use strongly influence individuals' intentions to adopt new technologies. Pratama (2021) similarly reported that Indonesian secondary school students' acceptance of mobile learning is primarily influenced by intrinsic motivation and perceived usefulness rather than previous technological experience. Likewise, Staacks et al. (2022) explained that Phyphox was specifically designed with an intuitive user interface that enables first-time users to conduct scientific experiments without requiring extensive technical training. Such characteristics make the application particularly suitable for vocational education, where students possess diverse technological backgrounds.

Furthermore, Tanti et al. (2024) found that smartphone-assisted laboratory activities significantly improved students' confidence and motivation in learning physics. Ürek (2024) also demonstrated that mobile laboratory applications enhance students' digital literacy while encouraging more active participation in science learning. These findings indicate that integrating smartphone technology into physics instruction offers both cognitive and affective benefits, extending beyond improvements in conceptual understanding alone. Collectively, these results suggest that students at SMKN 1 Prabumulih possess a high level of readiness to adopt Phyphox-based PhysicsLab despite their limited prior exposure to the application. The combination of high technology acceptance, institutional support, and widespread smartphone ownership establishes favorable conditions for implementing smartphone-assisted experimental learning within vocational physics education.

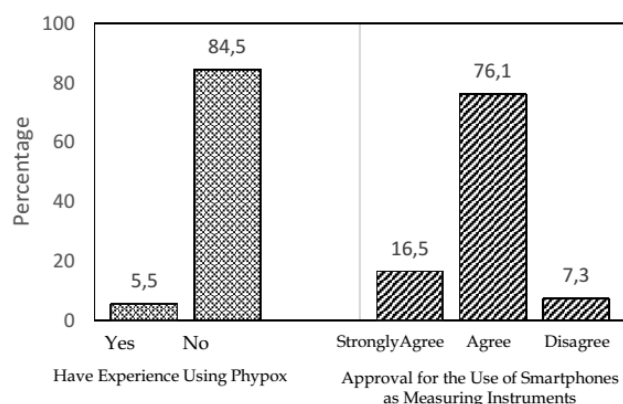


Figure 4. Adoption of phyphox-based mobile learning technology

Mobile Learning Feature Needs and SPS Needs

The final indicator examined students' expectations regarding the features of the proposed PhysicsLab

mobile learning application. As shown in Table 4, 52.30% of students preferred a comprehensive application integrating step by step laboratory guidance, real-time data visualization, and an interactive interface. Moreover, 75.20% strongly expressed the need for self-directed learning materials designed to develop Science Process Skills (SPS), whereas only 0.90% considered such materials unnecessary. These findings indicate that students expect mobile learning to provide a complete learning environment rather than merely delivering instructional content. The demand for integrated features reflects students' need for independent experimentation, interactive learning, and real-time scientific investigation. This result is consistent with the limited laboratory opportunities identified earlier, suggesting that students seek alternative learning media capable of supporting both practical activities and SPS development.

Table 4. Mobile Learning Feature Requirements and SPS Requirements

Features	f	% (n=109)
Desired Mobile Learning Features (Item 13)		
All features (step by step guides + real time data + interactive UI)	57	52.30%
Step by step lab guides only	34	31.20%
Real time data display only	10	9.20%
Engaging and interactive interface only	8	7.30%
Need for SPS-Based Self-Directed Learning Materials (Items 14–15)		
Yes, very much needed	82	75.20%
Possibly needed	26	23.90%
Not needed	1	0.90%

Table 5. Summary of Key Findings from the Needs Analysis

Indicator Domain	Main Findings	Implication
Smartphone Ownership	99.10% own a smartphone; 90.80% have permission from their school	No additional hardware is required for implementing mobile learning
Perception of Physics	54.10% like physics; 42.20% are neutral	Mobile learning can turn a neutral attitude into active engagement
Learning Challenges	55.00% too much theory; 53.2% not enough lab work	Phyphox offers an experiment-based alternative to textbook-based learning
Frequency of Lab Sessions	98.20% of the lab sessions were inadequate; 61.50% preferred experiments	The urgent need for portable and easily accessible laboratory alternatives
Technology Adoption	94.50% have never used Phyphox; 92.70% accepted smartphones as lab tools	High adoption potential with minimal barriers
Feature Requirements & SPS	75.20% are in urgent need of SPS media; 52.30% want all features	PhysicsLab must integrate guides, real-time data, and an interactive UI

These expectations are supported by previous studies demonstrating the educational benefits of mobile learning. In the Indonesian context, STEM-based mobile learning applications have significantly improved students' physics learning outcomes (Fathurohman et al., 2023). Furthermore, by integrating laboratory guidance, real-time data visualization, and interactive features, mobile learning can transform passive content consumption into active scientific inquiry. (Siswanto et al., 2025) confirmed through a systematic review that

mobile learning consistently enhances self-directed learning effectiveness in physics when these elements are thoughtfully combined. The 75.2% strong demand for SPS-based materials is particularly significant because it indicates that students are not merely seeking entertainment or convenience they explicitly recognize the need to develop scientific process competencies and actively desire learning tools that support this development. This finding aligns with the broader SPS deficit documented in this study and confirms that

PhysicsLab must be designed with deliberate SPS scaffolding embedded throughout its features, learning activities, and assessment components. Overall, the findings indicate that students at SMKN 1 Prabumulih possess the technological readiness and strong need for Phyphox-based mobile learning despite limited laboratory experiences. The combination of high smartphone ownership, strong technology acceptance, and deficiencies in Science Process Skills supports the urgency and feasibility of developing PhysicsLab mobile learning. Moreover, this study provides an empirical basis for designing PhysicsLab tailored to the needs of vocational high school students, extending previous studies that mainly focused on Phyphox implementation (Evains et al., 2024; Firdaus et al., 2024).

Conclusion

Based on a needs analysis conducted with 109 10th-grade students at SMKN 1 Prabumulih, the findings collectively underscore the urgency and feasibility of developing the PhysicsLab mobile learning application supported by Phyphox. Technological infrastructure is widely available, with 99.10% of students owning a personal smartphone and 90.80% having received school permission to use it for learning. However, 98.20% of students comprising 71.60% who rarely and 26.60% who never participate in laboratory activities do not receive adequate hands-on laboratory experience, despite 61.50% identifying hands-on experiments as the most effective method for understanding physics. Although 94.50% of students had never previously used Phyphox, technology acceptance reached 92.70%, indicating high adoption potential with minimal barriers. Furthermore, 75.20% strongly need Science Process Skills (SPS) based self-directed learning materials, and 52.30% desire comprehensive features integrating step-by-step guides, real-time data displays, and interactive interfaces. These findings establish that Phyphox-based mobile learning on measurement and physical quantities is technically feasible given the near-universal availability of student devices, pedagogically necessary given the documented deficit in students' Science Process Skills, and socially acceptable given the high level of technology acceptance among students. The development of PhysicsLab mobile learning is therefore well-justified and urgent as an effective, accessible, and contextually relevant physics learning medium for vocational education in Indonesia. Future research is recommended with a broader and more diverse sample from various vocational high schools across different regions to strengthen the generalizability of the findings. Further studies could also explore the full design and development of the PhysicsLab mobile learning application using the complete 4D development model, evaluate its impact on

students' SPS improvement, and investigate its effectiveness across different vocational programs and educational contexts in Indonesia.

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Author Contributions

Conceptualization, A.P. and I.; methodology, A.P. and I.; validation, I. and L.M.; formal analysis, A.P.; investigation, A.P.; resources, A.P.; data curation, A.P.; writing—original draft preparation, A.P.; writing—review and editing, I. and L.M.; visualization, A.P.; supervision, I. and L.M.; project administration, A.P. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest

The authors declare no conflict of interest.

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