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Research Artikel

ENHANCING STUDENTS' DATA LITERACY THROUGH THE HYBRID CREATIVE PROBLEM-SOLVING LABORATORY (HCP-LAB) IN PHYSICS EXPERIMENTS COURSES

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Abstract

Physics learning is inherently grounded in inquiry-based processes, particularly through experimental activities that engage students in observing physical phenomena. These observations are subsequently analyzed and interpreted to develop conceptual understanding, making data literacy an essential competency in physics education. However, many schools face challenges in conducting laboratory activities due to the high costs associated with procuring and maintaining experimental equipment. Moreover, conventional laboratory practices often fail to explicitly integrate data literacy as a core component of the learning process. To address these challenges, this study proposes an alternative approach that utilizes readily available devices, such as smartphones, as experimental tools. As a pilot project, a Hybrid Creative Problem-Solving Laboratory (HCP-Lab) model was developed and implemented to enhance students' data literacy skills in an introductory physics laboratory course. The study adopted Plomp's Educational Design Research framework and involved 28 first-year physics students, divided into two classes (15 students in Class A and 13 students in Class B). Data was collected over an eight-week period using data literacy assessments, student development observation sheets, and portfolio evaluations. Quantitative data were analyzed using descriptive and inferential non-parametric statistical techniques, while qualitative data were examined using NVivo software. The findings indicate that the HCP-Lab model effectively supported the development of students' data literacy skills, with observable improvements throughout the intervention. Students demonstrated notable progress in data processing, interpretation, and evidence-based conclusion drawing. Statistical analysis revealed a significant difference between pre- and post-intervention data literacy performance ($p < .05$). In addition, students reported that the HCP-Lab model provided a novel, engaging, and comprehensive laboratory learning experience. These findings suggest that the HCP-Lab model offers a viable alternative for physics laboratory instruction, particularly in educational settings with limited access to conventional laboratory equipment, while simultaneously fostering essential data literacy competencies.

Keywords: *Data literacy; digital learning; experiment model; HCP-lab; smartphone sensor.*

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INTRODUCTION

The study of physics involves an inquiry-based methodology as the foundation of learning process (Bao & Koenig, 2019; Bogador et al., 2024; Thacker, 2023) Inquiry offers students the chance to actively investigate natural phenomena, comprehend the resulting patterns, and formulate concepts based on empirical observations (Morris, 2025; Safkolam et al., 2024). This methodology is extremely important to scientific experimentation, a fundamental technique in physics education, wherein students engage in the examination of physical phenomena through observation, data acquisition, analysis, and the formulation of conclusions from experimental results (Holmes & Bonn, 2015; Szott, 2014).

To execute these activities, competencies are required that allow students to comprehend and interpret the information they observe. This skill is referred to as data literacy. The crucial purpose for data literacy has increased alongside the rapid advancement of technology and the growing complexity of data in physics education, which requires data literacy as an essential competency for students (Morris, 2025; Safkolam et al., 2024).

Data literacy encompasses the capacity to read, analyze, and critically interpret experimental data with precision (Kuhn, 2023). In the context of physics education, data literacy helps students to recognize patterns from experimental results, thereby forecast physical phenomena, and associate them with relevant theories (Smalheiser, 2017; Suryadi et al., 2021). Furthermore, students must analyze and illustrate data using tables, graphs, or mathematical models, and interpret the relationships between variables and in line with pertinent physical principles (Bach et al., 2023; Greca & Moreira, 2002; Woolnough, 2000). At an advanced level, data literacy contributes to the enhancement of critical thinking skills through the assessment of data reliability, the comparison of experimental outcomes with theoretical predictions, the formulation of evidence-based conclusions, and effective scientific communication (Byrd & Asunda, 2020; Hamid & Cui, 2024; Sandoval-Ríos et al., 2025; Wise, 2022).

However, lots of schools, particularly in resource-limited, deal with issues with facilitating physics laboratories. High costs and limited access to laboratory equipment are significant obstacles to the implementation of inquiry-based learning. Consequently, students' opportunities to directly investigate physics concepts are constrained, potentially affecting their conceptual comprehension and scientific abilities (Li, 2024; Nzabahimana et al., 2024).

An innovative approach is required to deal with these two issues, one that diminishes dependence on costly laboratory equipment while integrating data literacy as an essential element of experimental activities. To address the initial issue, we presents a solution utilizing devices readily available to students, such as smartphones. (Nuryantini et al., 2020, 2022, 2023). Smartphones contain a natural ability to function as measuring instruments via integrated sensors, including cameras, accelerometers, magnetometers, and microphones to support a variety of physics experiments (Malik et al., 2020; Nuryantini et al., 2018, 2020, 2021; Odenwald, 2020; Pili et al., 2018; Sans et al., 2013; Zakwandi et al., 2021).

The utilization of smartphones in physics experiments exceeds simply handling of equipment restrictions, facilitating the establishment of learning environments aimed at enhancing data literacy. By combining digital features, students can actively engage in various measurement processes (Zhao, 2026). The variability of measurement results displayed on smartphones can manifest in various formats, such as individual numbers, tabulated data, or graphical representations (Geyer et al., 2022). This variety enhances students' analytical abilities and fosters the cultivation of data-driven thinking habits. The incorporation of technology into experimental activities facilitates a more contextual learning experience, enabling students to connect observations to real-world phenomena more significantly.

To address the second issue, this study proposes a lab activity design that focuses not only on the experimental process, but also on the development of meaningful data processing and analysis skills. These sequences of activities is organized systematically within a lab model known as the Hybrid Creative Problem-Solving Laboratory (HCP-Lab) model.

The HCP-Lab integrates hybrid learning through the combination of physics experiments that emphasize the measurement and control of variables with smartphone sensors to facilitate data collection and develop creative problem solving (Nuryantini et al., 2022). This model enables students to perform traditional laboratory procedures while also experiencing complex scenarios that necessitate creative and analytical problem-solving skills in data analysis (Zakwandi et al., 2024). This model enables students to investigate data, recognize patterns, verify results, and communicate findings scientifically.

This model was designed to establish a more contextual, applicable, and relevant learning experience. It is specifically aimed at dealing with the challenge of enhancing physics students' data literacy and research in the digital era (Doherty, 2020; Leon-Urrutia et al., 2020).

Moreover, the HCP-Lab is designed to enhance data literacy alongside promoting critical, creative, and collaborative thinking skills. This model's activities are designed to develop students' confidence, especially in dealing with data-driven physics problems, thereby improving the readiness of students for academic and professional challenges.

Based on the identify issue, this study addresses the following research questions: 1) What are the characteristics of the HCP-Lab model in enhancing student data literacy? 2) What is the effect of implementing the HCP-Lab model on enhancing student data literacy? 3) What is the students' response to the activities in the HCP-Lab model?

This study specifically attempts to evaluate the Hybrid Creative Problem-Solving Laboratory (HCP-Lab) model as a novel method for experiment-based learning. The results are expected to point out the impact of the HCP-Lab model and its potential for extensive application in diverse educational contexts.

METHOD

This study adopts the Educational Design Research (EDR) methodology established by Plomp (2013), which is implemented through systematic phases to design, develop, and analyze the impact of learning interventions. By employing this methodology, we endeavor to develop alternative instructional strategies and evaluate their impact on enhancing student data literacy.

This research is divided into three primary phases: prototype exploration, implementation, and evaluation and reflection. During the prototype exploration phase, researchers performed a preliminary evaluation of the HCP-Lab model, which includes a needs analysis, literature review, and the development of research instruments. The outcome of this phase was prototype version 1.

The validation of prototype 1 was conducted via focus group discussions (FGD) with team of lecturers of the fundamental physics experiment courses consisting of 7 lecturers, 3 laboratory assistants, and 1 laboratory technician (PLP). Feedback from these experts was utilized to enhance and improve the preliminary design, which resulted in prototype version 2.

During the implementation phase, prototype version 2 was academically evaluated through two activities. First, a training program was administered to laboratory assistants as experienced users to ensure awareness and proper implementation of the design. Then, the model was also applied to evaluate the effects of the learning facilitated by the model.

Within the implementation phase, this study began with an initial data literacy test in the first week to determine students' initial abilities. Furthermore, between the second and seventh weeks, students participate in a series of fundamental physics experimental activities that include group discussions, case study analysis, and the use of data analysis software. In the eighth week, a final data literacy test was administered, and a portfolio was compiled as part of the final learning evaluation. The outcomes of this implementation informed successive improvements, resulting in prototype version 3.

The evaluation and reflection phase was carried out afterwards to data collection from the implementation. At this stage, the researcher performed an assessment and reflection through structured discussions with experts (4 lecturers, 3 laboratory assistants, and 1 PLP) to evaluate the feasibility, academic performance, and academic deficiencies of the developed model. The findings of this assessment were utilized to develop prototype version 4 as the definitive product of this research. The entire structure of this research phase is illustrated in Figure 1.

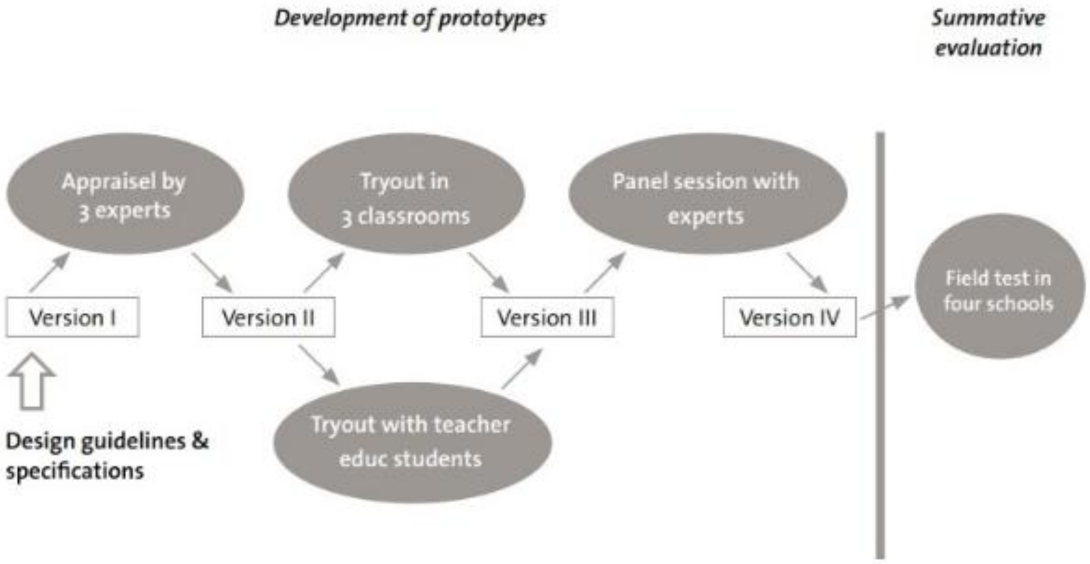

Figure 1. Research Procedures (Plomp, 2013)

The participants in this study consisted of 28 first-year students enrolled in a fundamental physics laboratory course, categorized into two cohort classes: Class A (15 students) and Class B (13 students). Both classes have been selected through intact group sampling, utilizing class groups that had been organically developed within an academic setting.

This study involved both classes receiving identical treatment via the HCP-Lab model, resulting in the aggregation of data from both classes for analysis as a unified group. This methodology was employed to assess the intervention's efficacy in a practical educational setting without a control group, while preserving the integrity of classroom dynamics. Thus, the findings of this study are more focused on contextual generalization (analytical generalization) rather than statistical generalization to the wider population (Obilor, 2023; Worku et al., 2026).

The research instrument for this study was developed to address RQ2 and RQ3, whereas RQ1 was examined through open discussions in FGD activities without the use of specifically structured instruments. This methodology was selected as RQ1 emphasizes the examination of the HCP-Lab model's characteristics, providing comprehensive insights by in-person interaction with experts and practitioners.

This research employed a written test comprising 16 questions to assess the learning impact (RQ2), including 13 multiple-choice questions and 3 open-ended questions. Each question item is carefully constructed to assess aspects of data literacy within the domain of physics experiments courses, including understanding of data context, measurement, analysis, and interpretation of experimental data. Particularly for open-ended questions, a single item assesses multiple competencies (multidimensional), resulting in repetition in the aspects evaluated. Hence, this instrument assesses both conceptual mastery and students' ability to scientifically process and interpret data. Table 1 provides a comprehensive presentation of the question item development matrix that encompasses aspects of data literacy.

Table 1. Matrix of Data Literacy Test

Data Literacy Aspects	Code	Item
Data Awareness	DAW	1, 5, 6
Data Collection	DCO	2, 3, 10, 11
Data Quality & Accuracy	DQA	7, 8, 9, 13
Data Representation	DRE	4, 15, 16
Data Analysis	DAN	8, 14, 15
Data Interpretation	DIN	14, 15, 16

Additionally, to address RQ3 concerning student feedback to the learning activties, an instrument of open-ended questionnaire was established. This instrument attempts to investigate students' perceptions in extensive detail with respect to the implementation of HCP-Lab, focusing on the perceived learning experience, challenges experienced during experimental activities, recommendations for further development, as well as the level of acceptance for the model's future utilization. This qualitative methodology enables researchers achieve deeper insights and contextual information to inform the development of learning models.

Data analysis was conducted using both quantitative and qualitative approaches (Creswell, 1999). Quantitative data from the literacy test was analyzed descriptively to describe the pattern of student scores and non-parametric inferentially using Wilcoxon and Mann-Whitney to test the significance of differences in initial and final test results.

Meanwhile, Qualitative analysis was performed in multiple stages: open coding, categorization, and thematic interpretation utilizing NVIVO. The primary author executed the initial coding process, utilizing an appropriate analytical framework. The coding results were subsequently evaluated and deliberated upon with all authors via a Focus Group Discussion (FGD) to achieve consistency on categories and themes (Mason, 2002).

This study utilized investigator triangulation techniques to enhance the validity of the analysis by involving multiple researchers in the interpretation process and engaging in thorough discussions to reduce subjective bias. Additionally, an audit report was meticulously recorded during the data processing procedure.

RESULTS AND DISCUSSIONS

RQ1: The characteristics of the HCP-Lab experiment model

The HCP Lab model comprises multiple phases of learning activities. In the initial phase, students are provided with a worksheet that illustrates the relevance of the experimental activities for real-life application. This part is conducted asynchronously, requiring students to familiarize themselves with the equipment and experimental protocols to be executed in the synchronous part. Furthermore, the worksheet is designed to assist students with essential prior knowledge helpful for the forthcoming experiments (Schauble et al., 1995; Stofflett & Stoddart, 1994; van Riesen et al., 2022)

The second phase involves a collaborative brainstorming session between instructors and students. This activity is performed in-person in a classroom for 30 to 90 minutes to ensure students understand basic knowledge before conducting data collection. The activity involves ensuring that students reconsider tool safety, potential hazards resulting from experimental carelessness, and critical considerations when utilizing smartphones during laboratory activities. (Clement, 1993; Schmidt et al., 1989). However, it can be modified, given that during the implementation phase at the pilot project, one experimental cycle is scheduled for 5 hours.

The third phase is defined as the laboratory experiment. After the attainment of verification and compromise in the second phase, students proceed to become involved in practical discussions to design and organize responsibilities for the experimental activities. Additionally, at this point, students propose data collection strategies and data processing techniques. This is essential for practicing experimental skills, as students must identify the requisite data for analysis (Idris et al., 2022; Moser & Korstjens, 2018; Phillips & Stawarski, 2008; Winne, 2022). It is important to acknowledge that while laboratory guidelines are available, students are not provided with specific information concerning the data they will collect during the practicum. These points to the measured variables derive from discussions with teammates.

The fourth phase is the measurement stage, which involves data collection. At the moment, students collect data while following laboratory safety protocols. The data collection process, assisted by a laboratory assistant, emphasizes the utilization of physical measurement principles. Measuring data is subsequently processed using data analysis software, such as Excel or Origin. On-site data processing enables students to identify outliers and, if required, to reiterate the measurement procedure to acquire more precise data.

The fifth phase involves data analysis and presentation. Practical activities are intended to be executed collaboratively, encompassing all stages from preparation to reporting. Upon data collection, students are instructed to analyze the findings systematically. The analytical process is conducted collaboratively with the preparation of presentation materials. At the end of the meeting, each group presented their experimental results to the class and received feedback from other groups. This talk allows students to criticize and further develop their comprehension of the experimental findings (Katchevich et al., 2013; Kolodner, 2002; Rahman et al., 2011; Wen et al., 2025). Finally, students independently prepare a final report and create a video presentation asynchronously as a post-class learning activity.

RQ2: The effect of implementing the HCP-Lab model on enhancing student data literacy

During the implementation phase, data was collected to assess the extent to which the HCP-Lab model improved students' data literacy in the context of experimental tasks. Figure 2 shows a boxplot of the results of the data literacy pre-test and post-test.

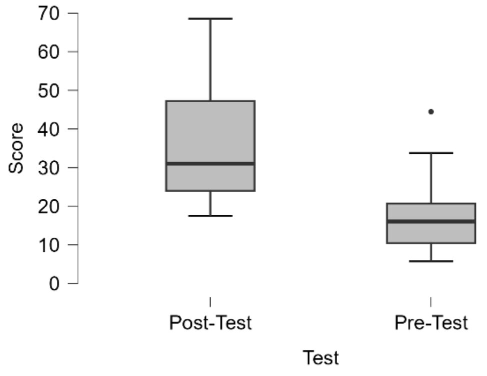

Figure 2. Boxplot Description

Test scores are on a descriptive scale from 0 to 100 and indicate the level of competence of data literacy of students. The analysis showed a large effect size increase in the average score from 17,12 (SD = 8,94) in the pre-test to 35,17 (SD = 15,03) in the post-test. The average difference of 18.05 points indicates that students' data literacy skills improve after the application of the HCP-Lab model. This achievement was considered as a practically meaningful improvement, from the low to the moderate category, based on the score range.

In addition, the higher value of the standard deviation in the post-test than the pre-test indicates that there is more variation in the scores of the students. This would suggest that the response to the learning intervention was not homogenous with some students showing significant improvement and others more moderate improvement. This variation demonstrates the differences of individual characteristics in responding to the implementation of the HCP-Lab model and also indicates that this model has diverse impacts on the development of the students' data literacy. (Fuchs & Fuchs, 2006; Zee et al., 2016).

The upward trend in average scores, as well as increasing variability in outcomes, suggests that the intervention was mostly effective, while also highlighting the necessity of addressing individual student differences. The variation in results is likely affected by multiple factors, including initial ability (Shana & Abulibdeh, 2020), motivation (Esparza et al., 2020), and learning environment (Alam & Mohanty, 2023).

To support these findings, additional statistical analysis was performed to assess data distribution, homogeneity, and the impact of the intervention. The findings of this statistical analysis are presented in Table 2.

Table 2. Statistical Analysis

	Pre-Test	**Post-Test**
Normality Test (Kolmogorov-Smirnov)	0,040	0,063
Homogeneity	0,000	
Non-Parametric Test (Asymp. Sig. (2-tailed) Wilcoxon)	0,000	

The Kolmogorov–Smirnov test for normality indicated that the pre-test data were not normally distributed (p = 0,040; p < 0,05), whereas the post-test data were normally distributed (p = 0,063; p > 0,05). The homogeneity test results revealed a significance value of 0.000 (p < 0,05), indicating that the data variance is heterogeneous. Following these characteristics, the analysis proceeded with the non-parametric Wilcoxon signed-rank test to assess the differences between pre-test and post-test scores. (van der Loo & De Jonge, 2018).

The Wilcoxon test results indicate an Asymp. Sig. (2-tailed) value of 0.000 (p < 0,05), implying a statistically significant difference between the pre-test and post-test scores. This finding offers compelling evidence that the intervention implemented enhanced student abilities (Rey & Neuhäuser, 2011). The improvement in the average post-test score confirms the earlier descriptive analysis indicating enhanced student performance following the implementation of the HCP-Lab model.

However, the analysis demonstrated considerable variability in data among students. This suggests that individual factors and the learning context can affect responses to interventions. As a result, additional research should examine factors affecting this variation, including disparities in initial competencies or learning environments. Moreover, comprehensive documentation of the intervention implementation process may be helpful in identifying reasons of data variability. Additional research with an expanded sample size is advised to enhance data distribution stability and extend the generalizability of the results.

Further investigation involved assessing enhancements in data literacy across all dimensions, as illustrated in Figure3.

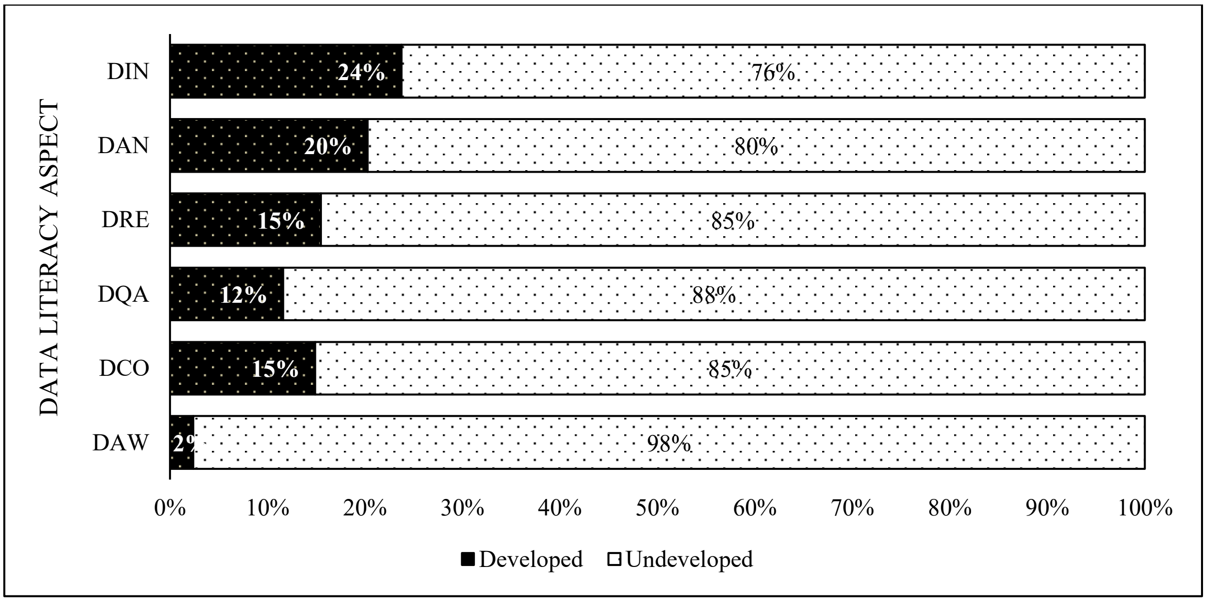

Figure 3. Percentage of HCP-Lab Contribution into Data Literacy for Each Aspect.

The results indicate that student performance differed across various aspects, with the majority designated as poor growth. Of all improvements were observed in data interpretation (24%) and data analysis (20%), suggesting that the HCP-Lab intervention was effective in developing the processing and interpretation of experimental data.

In contrast, data awareness exhibited the minimal enhancement at 2%, reflecting that fundamental competencies in understanding the context and usefulness of data have not yet substantially progressed. Additional factors, including data quality and accuracy (12%), data collection (15%), and data representation (15%), exhibited minimal enhancement. This indicates that fundamental skills in data collection, data quality maintenance, and data representation have not yet been fully developed through the intervention.

This pattern implies that the HCP-Lab model exerts a more significant influence on the establishment of data analysis and interpretation skills than on the foundational elements of data literacy. A potential reason for this is the character of the learning activities, which prioritize problem-solving and data analysis (Saleh et al., 2022; Wu & Molnár, 2022).

RQ3. Student Feedback

Despite the slight development in student data literacy, responses to the HCP-Lab model were notably positive. Qualitative analysis highlighted three primary themes: (1) adaptation to the laboratory workflow, (2) the extensiveness and openness of the laboratory process, and (3) the benefits of presentation sessions as a collaborative learning platform.

In the first theme, students expressed their fascination at the experimental activity pattern, which contrasted with traditional laboratory work. Over time, they began to become familiar with as well as embrace the more dynamic and challenging learning environment. A student mentioned,

"*At first, I was surprised because this practicum was different from usual, but over time, I got used to it, and it even felt exciting because there were many new things to learn.* (Student A)"

The findings indicate that although initial modifications to the practicum model may pose difficulties, a successful adaptation process can enhance student comfort and engagement in experimental activities. These findings are consistent with the findings reported by Wang et al. (2022), who declared that initial challenges in adjustment to an inquiry-based experiment framework might promote the improvement of students' critical thinking abilities. This is crucial to the nature of the experimental activities in the HCP-Lab, which necessitate students proactively pursuing solutions to the challenges they experience.

The second theme, specifically the completeness and clarity of the practicum process, is evident in students' perceptions of the systematic organization of activities, particularly with respect to data analysis guidelines. A student pointed out:

"*In class, we have been given clear directions on data analysis. So, I must complete it at home because most of it has been done together in class.* (Student B)"

This approach helps prevent student confusion in understanding and performing data analysis, while simultaneously enhancing time efficiency in independently exploring the analytical process. This illustrates that the design of established laboratory activities may facilitate the learning process.

The complexity of the HCP-Lab design aligns with the finding of Feisel and Rosa (2005), who pointed out that laboratories with explicit procedures could reduce student confusion, enhance time efficiency, and promote a higher focus on data interpretation rather than technical details. Moreover, the analytical guidance proposed during class activities highlights the effective use of scaffolding, which, as mentioned by Hofstein and Lunetta (2004), is essential for assisting students to complete academic assignments independently.

The third theme, the advantages of presentation sessions as a collaborative learning platform, was clearly reflected in the students' appreciation of the presentation activities at the conclusion of the practicum. A student mentioned,

"*The presentation session at the end was very helpful. If something is unclear or wrong with our analysis, other groups can give feedback, and we can also learn from them.* (Student C)"

This session helps students to participate in critical discussions, providing constructive feedback and contributing to the analysis of other groups as well. This interaction develops conceptual understanding and further develops This presentation session addresses the potential benefits of collaboration, which correspond with the significance of social and academic interaction in learning, especially within the Zone of Proximal Development (ZPD) framework (Fani & Ghaemi, 2011). During discussion discussions, students may suggest corrective feedback and enhance each other's understanding. Moreover, Ibáñez and Delgado-

Kloos (2018) discovered that group presentation activities in STEM education enhance reflective thinking skills, resolve analytical errors, and expand conceptual understanding.

Overall, positive student responses indicate that the applied practicum model was effective in developing a learning environment that facilitated adaptation, knowledge acquisition, and critical engagement. Students experienced more well equipped for dealing with the challenges of data analysis after participating in well-organized yet flexible activities. They also developed confidence in collaborating and presenting their results. These findings are consistent with active learning principles, which emphasize the value of hands-on experience, reflection, and discussion in developing deep conceptual understanding.

Moreover, the findings of this study present considerable practical impact, especially for educational institutions with tight laboratory resources. The HCP-Lab model provides a more adaptable solution for executing hands-on tasks by facilitating the utilization of readily available devices, including smartphones and data analysis software. This approach enables the meaningful conduct of experiments without completely dependent on costly or limited laboratory equipment. Also, the activity framework, which integrates in-person and self-directed learning, improves the effective utilization of time and resources.

Finally, from an implementation evaluation, this model is appropriate in contexts where students are familiar with simple digital devices and receive limited assistance through structured lab guides and initial supervision from instructors or laboratory assistants. In this context, HCP-Lab functions as a flexible solution to enhance the quality of hands-on instruction while systematically developing students' data literacy. Hence, this model is both pedagogically effective and practically applicable across diverse learning environments, including those with limited resources.

The findings of this study suggest that the HCP-Lab model may serve as an attractive alternative for hands-on instruction, especially for educational institutions with limited laboratory resources. A principal contribution of the model is the utilization of readily available devices, such as smartphones, as sensor-based measurement instruments. This enables experimental activities to be conducted without complete dependence on traditional laboratory apparatus, which is typically costly and limited in availability. This method enables teachers to persist in implementing experiment-based learning while maximizing the utilization of available resources.

Moreover, the HCP-Lab structure, which methodically incorporates experimental activities, data analysis, and presentation, offers a definitive framework for performing experiments. This is particularly crucial in scenarios where laboratory assistance limits exist as students continue to receive focused instruction in executing measurements, analyzing data, and conveying results. This model not only mitigates equipment limitations but also enhances the quality of the learning process by prioritizing data literacy.

The implementation of HCP-Lab necessitates several prerequisites for optimal performance. Initially, students require access to fundamental digital devices, including smartphones, along with requisite applications for measurement and data analysis. Secondly, it is essential to devise structured and contextualized practical activities to ensure that technology is genuinely integrated with learning objectives. Third, the role of teachers is essential in offering scaffolding during the initial phases, especially in assisting students with understanding experimental methodologies and data analysis techniques.

Furthermore, this study mentions that developments of learning models must equilibrate improvement of fundamental and advanced aspects of data literacy. Explicit strategies must be developed to enhance data awareness, measurement accuracy, and data quality from the initial phases of experimental activities, facilitating comprehensive improvements in data literacy across all dimensions.

Given these circumstances, HCP-Lab is ideally suited for educational settings with restricted laboratory resources and limited access to digital technology. The HCP-Lab model serves as an adaptive and contextual method for preserving the continuity of experimental learning while enhancing students' data literacy skills.

CONCLUSION

The research successfully developed a model of Hybrid Creative Problem-Solving Laboratory (HCP-Lab) that is designed to support the improvement of students' data literacy in basic physics practicum. This model offers an alternative way to conduct experiments using readily available devices such as smartphones, especially in situations with limited laboratory facilities.

The results showed that the implementation of HCP-Lab was linked with improved student data literacy as indicated by significant difference between pre-test and post-test scores ($p < 0.05$). Furthermore, the qualitative data demonstrated that students reacted positively to the learning experience, especially in terms of increased engagement, the clarity of the data analysis process, and the opportunities for discussion and collaboration through presentation activities.

Overall, these results show that the HCP-Lab model is a promising learning approach to support the development of data literacy in the context of physics practicums. However, interpretation of these results needs to be done considering the limitations of the present study.

LIMITATION AND FURTHER RESEARCH

This study contains numerous drawbacks that must be considered when assessing the results. The limited sample size of 28 students and the primary focus on particular learning context restrict the statistical generalizability of the results to a wider population. Hence, the findings of this study are most effectively interpreted through the perspective of analytical generalization, functioning as a contribution to conceptual comprehension and the advancement of learning models in related contexts, rather than as statistical generalizations.

The disparity in student responses to the intervention indicates that the model's efficacy may be affected by individual factors and learning conditions, including initial abilities, motivation, and available instructional support. This indicates the necessity for additional research to thoroughly comprehend the factors affecting the model's successful implementation.

Considering these limitations, a further investigation should incorporate a larger and more heterogeneous sample size and evaluate the feasibility of the HCP-Lab model across different institutional contexts and educational levels. Additionally, further studies could investigate the model's adjustment to variations in academic resources and student characteristics to achieve an in-depth understanding of the model's efficacy and relevance.

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AUTHOR CONTRIBUTION

Conceptualization, R.Z.; methodology, R.Z., A.S.P., and IMS; software, R.Z., A.S.P, A.A.F.N., N.H.F., and R.A.A; validation, I.M.S and D.S.Z; formal analysis, R.Z.; data curation, A.S.P, A.A.F.N., N.H.F., and R.A.A; writing—original draft preparation, R.Z.; writing—review and editing, R.Z., A.S.P. and D.P; visualization, R.Z. and D.P.; supervision, I.M.S., and D.S.Z. All authors reviewed and approved the final manuscript, with collaborative efforts contributing to the successful completion of this research.

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