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Analysis of High School Students' Concept Mastery on Static Fluid Material through Problem-based Learning Assisted by Google Sites

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Abstract: The purpose of this study was to analyze the effectiveness of PBL assisted by Google Sites in improving students' mastery of static fluid concepts. The research used mixed method research, Sequential Explanatory design. The research subjects were students of SMAN 01 Candipuro class XI MIPA, consisting of 35 experimental class students and 35 control class students. Quantitative data obtained from pretest and posttest with multiple choice instrument questions. The results of the T test on the pretest (0.931) showed no difference in initial ability between classes, while the Mann-Whitney test on the posttest (0.000) showed a significant difference between the two classes. The effectiveness of PBL aided by Google Sites is shown by the N-Gain of the experimental class (0.77, high category) which is greater than the N-gain of the control class (0.39, medium category). Qualitative data obtained from interviews revealed that the features of Google Sites, the presentation of contextual problems through videos, images, articles, and the investigation stage helped students build their own concepts and overcome misconceptions. This finding shows that PBL assisted by Google Sites is effective in improving students' mastery of the concept of static fluid.

Keywords: Concept mastery; Google sites; Problem-based learning; Static fluid

Introduction

Static fluid is a fundamental concept in physics that has an important role, but is often a challenge for students due to its high level of complexity (Puspita et al., 2019). This material includes three main principles, namely Archimedes' law, Pascal's law, and hydrostatic pressure, which are the basis for understanding various physical phenomena related to fluids (Ringo et al., 2019; Serway & Vuille, 2014). However, there are still conceptual errors or misconceptions that students often experience related to the concepts of hydrostatic pressure, Archimedes' law, and Pascal's law (Minogue & Borland, 2016). Students' misconceptions about static fluids, especially in the concept of hydrostatic pressure, are still quite high. Many of them misunderstand the relationship between fluid depth and hydrostatic pressure exerted on an object (Rizkiyati et al., 2018). On the material of Pascal's law, students also experience misconceptions on the cross-sectional area between the two pistons and its relationship with the lifting force (Taruly et al., 2022). on the material of Archimedes' law, students are still found who experience misconceptions on the position of objects in the fluid and its relationship with buoyancy force (Pulu & Widia, 2022). Conceptual errors occur due to the limited daily experience of students in activating concepts related to their application in everyday life (Kuczman, 2017).

The number of misconceptions in static fluid material indicates the low mastery of student concepts (Azizah et al., 2022; Yadaeni et al., 2018). This is often caused by the incompatibility of the learning model with

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the characteristics of the material (Rosmiati & Ahmad, 2020). In fact, good concept mastery is the main key in the thinking process (Ryan et al., 2016). Therefore, an effective learning model is needed to improve student understanding. Problem-Based Learning (PBL) is a suitable model because it integrates real problems in the learning process (Aslan, 2021; Oktaweri & Festiyed, 2020; Rizqi & Yulianawati, 2020). Research shows that students who learn with PBL have better mastery of physics concepts than those who use conventional methods (Aristawati, 2018; Azizah et al., 2022). PBL is designed to help students build understanding through relevant and meaningful problem situations (Mirna et al., 2025; Oktaweri & Festiyed, 2020) and the provision of ill-structured problems, where the available information is not always sufficient to find a direct solution (Rizqi & Yulianawati, 2020). Thus, PBL can be a solution in overcoming students' low mastery of concepts in static fluid material.

Although Problem-Based Learning (PBL) has been proven effective in improving student learning outcomes, its implementation still faces various obstacles. One of the main challenges is the lack of physics conceptualization skills of teachers and the lack of operating digital technology that supports the optimal continuity of PBL (Pasinggi, 2023; Qhobela & Moru, 2020). In addition, time constraints are often an obstacle in implementing each phase of PBL optimally (Kurnia, 2017). The lack of technology utilization in learning also causes students to miss out on a more contextualized learning experience (Amisaliani et al., 2024). Another obstacle is the limited learning facilities, especially media that support this method, so that the application of PBL is not fully optimized (Samsinar, 2019; Sari et al., 2023).

In the era of rapid technological advancement, almost all aspects of life, including teaching and learning activities, have been digitally transformed (Baharuddin et al., 2022). Therefore, teachers need to be more active in utilizing digital technology to optimize learning. Based on this, media assistance is needed (Abdullah et al., 2024). Some studies have tried to integrate media in PBL, but still have limitations. For example, the development of PBL models assisted by the Lectora Inspire application can only be used on desktops, so it is less flexible, especially for device users with low specifications (Amisaliani et al., 2024; Nisa et al., 2023). Another study that implemented PBL with the help of the Sway website was also less than optimal because it was only used as a medium for delivering material without supporting each stage of PBL as a whole (Salamah et al., 2020). Therefore, alternative media that are more flexible and integrated in all stages of PBL are needed to improve learning effectiveness.

Web-based learning in learning can improve concept mastery and construct knowledge based on daily experience (Amali et al., 2023). Google Sites is one of the effective websites because it makes it easy for students to access learning materials and information (Hidayat et al., 2023; Irfan, 2021; Supartin et al., 2023). Khasanah & Amalia (2023) stated that Google Sites can be utilized as a platform for developing learning media. The PBL model assisted by Google Sites has advantages over previous research. In this study, each PBl syntax is integrated with Google Sites. The first is used to present various problem-based stimuli in the form of images, videos, and contextual news articles relevant to the concept of static fluid. In this study, the Google Sites inquiry landing also provided interactive e-LKPDs, additional Material were also included on the google site for the conclusion stage. Formative tests are available on Google Sites to measure student understanding in real-time. This integration of various learning media helps students overcome difficulties in visualizing the concept of static fluid.

Based on the problems described, research on the application of PBL assisted by Google Sites in static fluid learning is still limited and needs to be done. Therefore, this study aims to analyze the differences in concept mastery of high school students on static fluid material before and after the application of problem-based learning (PBL) assisted by Google Sites compared to students who use conventional learning. In addition, this study also aims to measure the effectiveness of the PBL learning model assisted by Google Sites in improving students' concept mastery. The results of the study are expected to contribute to teachers and schools in developing more effective learning methods, as well as helping to reduce misconceptions and improve mastery of static fluid concepts.

Method

This research applies mixed method research with Sequential Explanatory design. In this design, the researcher conducts quantitative research first and then conducts qualitative research to explain more deeply the quantitative results that have been obtained. This research design is illustrated in the Figure 1.

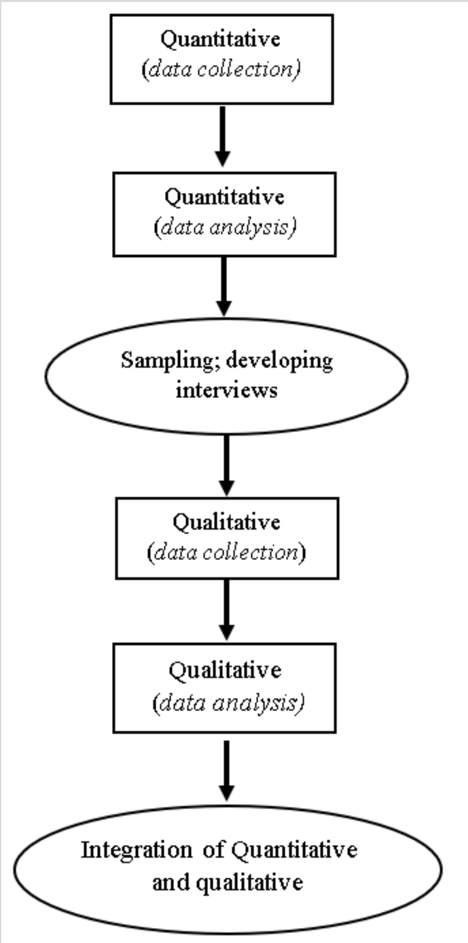

Figure 1. Sequential Explanatory Design

This This research consists of several stages. In the quantitative stage, researchers collected data through pre-test and post-test to measure concept mastery before and after learning using PBL assisted by Google Sites. Furthermore, in the third stage, researchers conducted a sampling process and interview development. This stage aims to determine the sample and the number of qualitative research samples and develop interview questions that can help explain quantitative results. In the qualitative stage, researchers collected data through in-depth interviews with a number of students to explore their experiences in PBL learning assisted by Google Sites. The last stage is the integration of quantitative and qualitative results. At this stage, researchers combine the two results to provide a comprehensive explanation of the effect of PBL learning model assisted by Google Sites on students' concept mastery on static fluid.

This study involved students of grade XI MIPA at Candipuro High School, Lumajang Regency. The research sample consisted of 1 control class that used convention learning (35 students) and 1 experimental class (35 students). Which uses PBL learning assisted by Google sites. The instrument used was a multiple choice test consisting of 10 questions used to measure mastery of the concept of static fluid. The questions consist of subchapters of hydrostatic pressure, Pascal's law, and Archimedes' law. Interview guidelines were also used as an instrument for qualitative data collection

In the Problem-Based Learning (PBL) learning model, there are 5 learning syntaxes, in this study each stage will provide google site assistance. The learning process begins with orienting students to the problem, where the teacher proposes contextual problems regarding static fluids in the form of videos and current news on the google site then gives their initial opinion. Next, the teacher organizes students to learn by forming groups. In the investigation stage, the teacher guides students in conducting investigations independently or in groups and directs them to collect the necessary data through E-LKPD available on Google sites. After that, students develop and present the results of their work through presentations in front of the class. The last stage is analysis and evaluation, where the teacher assists students in analyzing and evaluating the problem-solving process they have done.

Several quantitative data analysis techniques were used in this study. Descriptive analysis was conducted by calculating the mean, maximum score, and minimum score in each class. Furthermore, inferential statistical analysis was conducted using the SPSS 26.0 application starting with a normality test to determine the distribution of data. If the data is normally distributed, then a parametric test is conducted using an independent sample t-test on the pre-test and post-test. However, if the data is not normally distributed, the Mann-Whitney non-parametric test is used. This test aims to determine the difference in concept mastery between the two classes. After that, descriptive statistical analysis using N-Gain was conducted to assess the effectiveness of the PBL model on students' concept mastery on static fluid material. The N-gain formula is:

$$N - Gain = \frac{posstest\ Score - pretest\ score}{ideal\ score - pretest\ score} \quad (1)$$

Table 1. N-gain interpretation (Hake,1998)

G	Criteria
g> 0.7	High
0.3<g ≤ 0.7	Medium
g ≤ 0.7	Low

Qualitative data analysis was obtained from interviews conducted through several stages systematically, namely transcription, data reduction, coding, data distribution (cross-tabulation), data interpretation, and conclusion drawing (Creswell & Clark, 2017). The final stage of this research is to integrate the results of quantitative and qualitative data analysis to gain a more comprehensive understanding.

Result and Discussion

The research was conducted with a pretest at the beginning of the second meeting in both classes. The experimental class followed Problem-Based Learning with Google Sites for three meetings, while the control class used conventional learning for the same duration. The post-test was conducted at the end of the study in both classes. The results of the analysis of students' concept mastery on static fluid material can be observed in the research results below.

Descriptive Analysis

The analysis results display the results of the increase in the minimum, maximum, and average pretest and posttest scores in the experimental and control classes. More clearly can be seen in table 2.

Table 2. Descriptive statistical analysis

Desc.	Exsperiment class		Control class	
	Pre-test	*Postest*	*Pre-test*	*Postest*
N	35	35	35	35
Mean	30	83.71	30.29	59.71
St. Deviation	13.504	10.870	13.824	10.224
Minimum	10	60	10	40
Maximum	50	100	50	80

Although both classes experienced an increase in concept mastery test results, the maximum and minimum pretest values in both classes had the same value, while in the posttest the minimum and maximum values of the experimental class were greater than the control class. In addition, comparison of posttest and pretest scores can be seen in Figure 1.

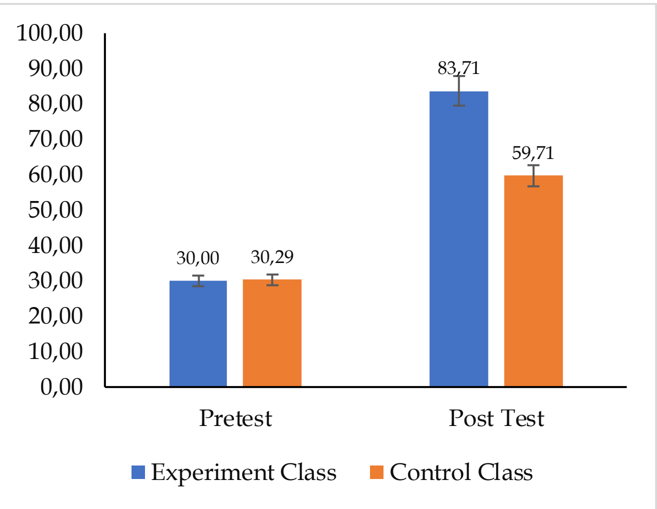

Figure 2. comparison of pretest and postest scores between experimental and control classes

The results of the analysis of pretest and posttest scores showed that both experimental and control classes experienced an increase in scores after being given treatment. The average pretest score in the experimental class was 30, which then increased sharply to 83.71 in the posttest. Meanwhile, in the control class, the average pretest of 30.29 only increased to 59.71 in the posttest. This striking difference in improvement indicates that the learning method applied in the experimental class had a greater impact on students' concept mastery than the method used in the control class. However, to ensure that the difference is statistically significant and not just a coincidence, inferential analysis is needed.

Inferential Statistical Analysis

Before conducting inferential tests, a prerequisite test is required, namely a normality test using one-sample Kolmogorov-Smirnov. This test aims to determine whether the sample is normally distributed or not. The results of the normality test can be seen in table 3.

Table 3. Normality test results

Class		Asymp.Sig(2-Tailed)	Categories
Exsperiment - class	Pretest	0.072	Normal
	Posttest	0.001	Not normal
Control class	Pretest	0.068	Normal
	Posttest	0.006	Not normal

The analysis results show that the Asymp.Sig (2-Tailed) of the pretest in both classes (experimental and control) is more than 0.05, which means that it is normally distributed. However, the Asymp.Sig (2-Tailed) results for posttest data in both classes show a value of less than 0.05 which means the data is not normally distributed. The non-normality of the posttest data indicates that for further statistical analysis, non-parametric tests are used because they do not rely on the assumption of normal distribution. Therefore, in this study, the test used to compare posttest results between experimental and control classes used the Mann Whitney test. Meanwhile, to compare the pretest results of the two classes, parametric statistics were used, namely the Independent Sample T-test as show in table4.

Table 4. T-test and mann whitney test results

	Test type	Sig. (2-tailed)
Pretest	Independent sample T-test	0.931
Posttest	Mann whitney test	0.000

The results of the Independent Sample T-test test on pretest data show a significance value (Sig. (2-tailed)) is greater than 0.05. This indicates that there is no significant difference between the experimental group and the control group before treatment. In other words, both groups had relatively similar initial abilities. Meanwhile, the Mann-Whitney test results on the posttest data showed a significance value smaller than 0.05. This indicates that there is a significant difference between the experimental group and the control group after the treatment. Thus, it can be concluded that the use of problem-based learning (PBL) model assisted by Google Sites has a significant effect on students' concept mastery in static fluid learning.

These results reinforce that the application of problem-based learning (PBL) model assisted by Google Sites is able to improve students' concept mastery better than conventional learning. The significant difference in the posttest shows that the intervention provided in the experimental group succeeded in creating a more meaningful learning experience, allowing students to be more active in analyzing problems, exploring concepts independently, and linking theory with real situations presented through Google Sites. In addition, these results are also consistent with the theory that PBL can improve students' mastery of concepts because students are directly involved in the process of finding solutions, not just passively receiving information (Azizah et al., 2022).

Descriptive Statistical Analysis

After knowing the difference between the experimental class and the control class, the N-gain test was conducted to determine the effectiveness of PBL learning assisted by Google sites.

Table 4. N-Gain result

Class	N-Gain
Experiment class	0.77
Control class	0.39

Based on the N-Gain results, the N-Gain value in the experimental class is included in the high category (N-Gain > 0.7), which indicates that the application of the problem-based learning (PBL) model assisted by Google Sites is able to significantly improve students' concept mastery. In contrast, the N-Gain value of the control class is included in the medium category (0.3 ≤ N-Gain < 0.7), which indicates that although there is an increase, the effectiveness of learning in this class is not as optimal as the experimental class.

Experimental class students experienced greater improvement because PBL encourages exploration, collaboration, and linkage of material to real contexts through Google Sites. In contrast, the conventional method made students more passive in the learning process. The striking difference in N-Gain shows that PBL assisted by Google Sites is more effective in improving concept mastery and compared to conventional learning.

Cross Tabulation

Cross tabulation is carried out on each question worked on by the experimental class to find out in more detail about the pattern of student answers given PBL learning assisted by Google sites. Of the 10 concept mastery questions given, one of the sample questions given was about hydrostatic pressure, this question was prepared based on the misconceptions experienced by students regarding the concept of measuring the depth of a point in the fluid presented in Figure 3.

Benda dimasukkan ke dalam kolam renang, yang memiliki kedalaman 10 meter. Manakah di antara pernyataan berikut yang nilai tekanan hidrostatis paling besar yang dialami benda tersebut?
A. Benda yang berada 6 meter di bawah permukaan
B. Benda yang berada 6 meter di atas dasar kolam
C. Benda yang berada 5 meter di atas dasar kolam
D. Benda yang berada 2 meter di bawah permukaan
E. Benda yang berada 2 meter di atas dasar kolam

Figure 3. static fluid test questions

An analysis of the answers given by students on this question is shown in Figure 4.

			POSTTEST						TOTAL
			A	B	C	D	E*	E**	
			5.71%	2.86%	0.00%	0.00%	91.43%	0.00%	
PRETEST	A	2.86%		1					1
	B	48.57%	2				15		17
	C	34.29%					12		12
	D	0.00%							
	E*	8,57%					3		3
	E**	5.71%					2		2
	TOTAL		2	1	0	0	32	0	35

Figure 4. distribution of student answers

Based on Table 4, three students maintained the correct answer (Option E) in the pretest and posttest with the right reason. The other two students still answered correctly, but experienced an improvement in mindset from pretest to posttest. Meanwhile, one student consistently chose option B, and two students kept choosing option A, indicating difficulty in understanding the concept of depth. In addition, 12 students changed their answers from C to E. From the pretest results, it can be seen that students experience misconceptions when determining the depth of a point in the fluid, but after the treatment, most students experienced a change in concepts regarding depth measurement and hydrostatic pressure relationships. To further understand the students' way of thinking, qualitative analysis through interviews was conducted.

Qualitative Analysis

Qualitative analysis helped identify why there was an increase in concept mastery in the experimental class with a high category. Interviews were conducted with experimental class students based on the results of cross tabulation. This was done to analyze one by one the misconceptions that occurred and changes in student concepts on the posttest. Where students who initially answered wrong on the pretest became correct on the posttest, answered right on the pretest became wrong on the posttest, and answered wrong on the pretest and postest. The following are the results of the qualitative analysis carried out based on the questions in figures 1 and 2

A total of 15 students changed their answers from B to E. To understand their mindset, interviews were conducted with the following results.

Researcher: "During the pretest, why did you choose answer B?"

Student: "I directly chose the object that is 6 meters above the bottom of the pool because I think that is the farthest point from the bottom of the pool, so the hydrostatic pressure is the greatest."

This is in accordance with the findings of Rizkiyati et al. (2018); Sholihat et al. (2017) who stated that there are still misconceptions about the relationship between depth and hydrostatic pressure. Where students do not know how to determine the depth correctly.

Researcher: "Then, why did you change your answer to E during the posttest?"

Student: "After doing the practicum and completing the e-LKPD, I understand that hydrostatic pressure depends on the depth of the object from the water surface. Initially, I didn't pay attention to how to read the position of objects in the pool. I then realized that an object that is 6 meters above the bottom of the pool actually has a depth of 4 meters from the surface, so I thought again and chose answer E."

Of the 35 students, as many as 20 students stated that if the orientation of students to the problem during PBL learning assisted by google site is interesting and helps them to relate concepts to real life, so that the concepts learned are easier to understand when doing activities on the E-LKPD.

Researcher: "From the learning process learning process that has been carried out, which part which part makes you understand the concept of static fluid?"

Student: "Problem orientation problem orientation at the beginning is very helpful, I can relate the concept of static fluid to the events around me. events around. So when working on e-LKPD it becomes easier, besides that all the learning stages have become one in the google site that makes it easier for me and my friends in learning".

Based on the analysis of students' answers to the questions and the results of interviews, it was found that students' mastery of concepts improved as indicated by 91.43% of students no longer experiencing misconceptions about hydrostatic pressure that is not influenced by fluid depth can be corrected through the problem orientation and investigation stages in the Problem-Based Learning (PBL) model assisted by Google Sites. Through this approach, students not only receive information passively, but also engage in concept exploration by observing real phenomena, conducting experiments, and discussing to find solutions.

A similar analysis was also carried out on the sub-material of Pascal's law, based on the results of the interview analysis regarding Pascal's law revealed that the misconceptions about the need for the same piston area for the largest lifting force identified in the pretest were successfully overcome through problem orientation and investigation in Google Sites, this was indicated by 88.57% of students choosing the correct answer on the posttest. Analysis of the interview results stated that in the pretest students likened the problem to previous experiences and knowledge that were not certain of the truth of the concept so that misconceptions occurred. This is in accordance with the research of Saouma et al. (2018) which states that most students will tend to connect new concepts with prior knowledge. By presenting contextual problems and guiding the exploration of Pascal's Law, students understand that the pressure in a closed fluid is transmitted evenly. This is in accordance with the research of Ningrum et al. (2021); Widiastuti et al. (2023) which states that the presentation of everyday problems in PBL can provide a positive stimulus for students. However, there are 11.43% of students who still experience misconceptions because they think that the pressure must be balanced in a related vessel which is caused by sticking to the real experience stance that is not in accordance with the concept.

Analysis of the Archimedes' law sub-material shows that if in the pretest students experience misconceptions of buoyancy force influenced by the mass of the object as found in previous studies (Dyah et al., 2019; Minogue & Borland, 2016) the results of cross tabulation show 94.29% of students experience changes in mindset and mastery of good concepts. Furthermore, these results were analyzed through interviews. These results confirm that PBL assisted by Google Sites is effective in improving concept mastery and overcoming misconceptions. However, there are 5.71% showing that students still experience misconceptions, this is corroborated by the results of interviews which show that students are mistaken because they connect concepts inappropriately with their daily experiences, and students find it difficult to solve the problems given to them.

The results of this qualitative analysis are in line with the Mann whitney results which state that there is a significant difference between the control and experimental classes and a higher N-Gain increase in the experimental class, indicating that the PBL approach assisted by Google Sites contributes positively. Based on the results of the interview, it shows that several syntaxes of PBL assisted by Google sites that play a role in helping to improve students' mastery of the concept of static fluid, including contextual problem orientation (Jamaludin & Batlolona, 2021) and presented on Google sites in the form of videos, images, and news articles. As well as in the investigation process that allows students to build concepts through collaborative activities with peers.

Problem-based learning was shown to reduce misconceptions, with significant improvements in the experimental class influenced by active student involvement, more effective learning strategies, and the utilization of technology in material exploration. PBL assisted by Google Sites allows students to learn independently, access various sources, and connect concepts with real situations, thus supporting face-to-face learning at school (Waraga et al., 2023). in contrast to the control class which is more conventional and less encourages active participation. This research is in line with the results of research by Yan et al. (2024) where PBL has a high influence on the mastery of physics concepts, including static fluids. Rosmiati & Ahmad (2020) found that PBL supports concept mastery through problem-based discussions. This study strengthens these findings by adding technology integration through Google Sites which is applied in all stages of PBL. Features such as multimedia presentation, interactive discussions, and systematic access to materials make the learning experience more structured and effective in learning. This is reinforced by previous research by Adhana & Andriani (2024); Sylvia (2022) regarding the effectiveness of interactive media that has a positive effect on learning. Therefore, this research contributes to developing a more optimal technology-based PBL model to improve students' concept mastery on static fluid material.

Conclusion

This study shows that Problem-Based Learning (PBL) assisted by Google Sites is effective in improving students' mastery of static fluid concepts. The T-test result on the pretest value (0.931) indicates that both classes have equal initial abilities. Meanwhile, the Mann-Whitney test on the posttest (0.000) indicated a significant difference between the experimental and control classes. The effectiveness of PBL assisted by Google Sites is reflected in the N-Gain of the experimental class (0.77, high category) which is greater than the control class (0.39, medium category), indicating a higher increase in concept mastery in the experimental class. Interviews revealed that Google Sites features, especially the presentation of contextual problems and stages of inquiry on the e-LKPD, helped students connect concepts to real life and reduce misconceptions. These findings support the application of technology-assisted PBL as an interactive, contextualized, physics learning strategy that can improve students' concept mastery. However, this study has limitations, such as a less stable network and not considering other variables that can affect students' final concept mastery. Therefore, further research is recommended to test the effectiveness of this model on other materials, expand the scope of variables analyzed, and explore supporting strategies to overcome technical constraints.

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Author Contributions

Conceptualisation, R. M. I., P. S., H. P.; methodology, R. M. I., P. S., H. P.; formal analysis, R. M. I.; investigation, R. M. I.; sourcing, R. M. I., P. S., H. P.; data curation, R. M. I and P. S.; writing-preparation of initial draft, R. M. I.; writing-review and editing, R. M. I; visualisation, R. M. I., H. P. All authors have read and approved the published version of the manuscript.

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Conflicts of Interest

The authors declare no conflict of interest and the funders had no role in the design of the study in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

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