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Enhancing critical thinking in Indonesian high school physics with physbook-powered problem-based learning

Binar Kurnia Prahani[1], Hanandita Veda Saphira[2], Eko Hariyono[3], Firmanul Catur Wibowo[4], Muhammad Abd Hadi Bunyamin[5]

[1]*Faculty of Mathematic and Natural Science, Universitas Negeri Surabaya, Indonesıa, Corresponding author, binarprahani@unesa.ac.id, ORCID ID 0000-0002-5606-6629*

[2]*Faculty of the Arts, Social Sciences and Humanities, University of Wollongong, Australia, ORCID ID 0000-0002-3609-952X*

[3]*Faculty of Mathematic and Natural Science Universitas Negeri Surabaya, Indonesıa, ORCID ID 0000-0002-1597-599X*

[4]*Faculty of Mathematic and Natural Science, Universitas Negeri Jakarta, Indonesıa, ORCID 0000-0001-9632-6061*

[5]*Faculty of Educational Sciences and Technology, Universiti Teknologi Malaysia, Malaysia , ORCID ID 0000-0002-8996-5372*

ABSTRACT

To align with Assessment and Teaching of 21st-Century Skills (ATC21S), especially in the area of Critical Thinking Skills (CTS), it is crucial to embrace educational innovations that depart from traditional approaches and to incorporate technological advancements into the educational process. This study seeks to (1) elucidate how the PBL model, with the support of PHysBook, is employed to enhance students' CTS, (2) delineate the enhancements in students' CTS resulting from the implementation of the PBL model with PHysBook assistance, and (3) characterize the student responses following the adoption of the PBL model supported by PHysBook to boost learners' CTS. This research follows a true experimental design with randomly assigned subject control groups and pre-test and post-test evaluations. The study encompassed 140 tenth-grade high school students, with a sample size of 104 students. The assessment of student activity in the control class has sufficient categories—the value of observation of student activities on CTS in the high category. There is a difference between O1 and O2 in class with the PBL model assisted by PHysBook in improving CTS with an increased rate in the high category with strong effect scores. The incorporation of PBL learning with PHysBook assistance to enhance CTS garnered positive feedback from students, making it a valuable innovation in the realm of education. In light of the study's limitations, it is recommended that future researchers explore similar investigations in different educational institutions or at various academic levels to compare the outcomes of CTS improvement.

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Introduction

In the pursuit of meeting the demands of The Assessment and Teaching of 21st-Century Skills (ATC21S), there is a realization of a modernized learning approach. This contemporary learning process necessitates the development of critical thinking (CT), creativity, effective communication, collaboration abilities, and innovative and scientific thinking (Astuti et al., 2019; Hastuti et al., 2019; Miras et al., 2023). In the twenty-first century, critical thinking skills (CTS) is crucial to allows students to be considerably more precise about what happens (Wafa & Jatmiko, 2022).

According to information from the Organization for Economic Co-operation and Development (OECD), the CTS of Indonesian schoolchildren remains quite low, science performance scores are nine from the bottom (71) from 79 countries (Lentika & Admoko, 2022). They were then, based on preliminary study data conducted in two Senior High Schools (SHS) in Surabaya, with a total of 190 students. A total of 171 learners fell into the category of low CTS, 19 learners fell into the category of medium CTS, and none fell into the high CTS. Thus, it can be seen that students' CTS level is still in the low category in physics subjects (Saphira & Prahani, 2022). Other findings, in research by Saphira & Prahani (2022), learning is still carried out with conventional learning models and learning media based on physical books and work on boards. As a result, poor CTS is now a critical issue that requires quick attention.

One subject that has many aspects related to the flow of CT is physics. Physics is based on experimental observations and quantitative measurements. The process of acquiring knowledge physics gives students the opportunity to hone their critical, creative, collaborative, and communication skills (the 4C's) (Estuhono et al., 2019; Khoiri et al., 2021a; Sarwi et al., 2019; Yuli et al., 2022). Physics learning strongly supports integrating technology to motivate students to provide interest, convenience, and exploration space for users. In order to get significant education, physics has to prioritize higher-order thinking skills (HOTs), mainly CT (Lestari & Winarto, 2022). For instance, Susetyarini et al. (2022) state that students' collaborative, critical thinking, creative thinking, and communication skills were in the good category. There was an increase in the first and second cycles through problem-based learning. The findings of this study are problem-solving-oriented learning can improve classical 4C skills.

Previous research by Wijayanto et al. (2021) shows that using PBL models is very good for physics learning. Educators have demonstrated for the past 50 years that PBL successfully enhances students' cognitive and social learning skills. Furthermore, Samadun & Dwikoranto (2022) concluded that applying the PBL model could improve students' CTS. Research by Prahani et al. (2022) shows that the utilization of Android-based educational tools for physics instruction is on the rise, and the ongoing digitization of physics learning is a gradual and continuous trend (Jatmiko et al., 2021). In line with research by Saphira (2022), mobile-based learning has increased publication trends over the past ten years. Thus, research on mobile-based learning is in demand by researchers, and there needs to be development and implementation in schools. Research by Bakri et al. (2021), Develop an Android-based Pocket Book application on physics learning. The resulting development shows that the product can be used effectively and efficiently. As well as research by Bani & Masruddin (2021) also developed research on Android-Pocket Book on harmonic oscillation material. The results show that android-pocket book learning media is effective for improving learners' cognitive learning outcomes (Rahmasari & Kuswanto, 2023), and learners tend to respond positively to android-based learning media. Based on the description above, in order to meet ATC21S, especially CTS, it is necessary to have learning innovations that are different from traditional learning and apply technological digitalization in the learning process (Negoro et al., 2024; Ristanto et al., 2022). Only now, previous research has been limited to the development and implementation of ability indicators or even no previous research at related high schools that implement e-pocket book-assisted PBL to improve CTS. Utilizing PHysBook to support the implementation of the PBL model offers the following benefits: 1) Can be accessed offline (without being connected to the internet); 2) The development can be adjusted to the material to be applied; 3) High compatibility and easy to operate;

4) No privacy data is stored; 5) In accordance with the problems and needs of students. However, to its initial development, PHysBook is still limited to Android operating systems and still in Indonesian Language. To further development its is will be upgrading to more variety operating systems and languages. Moreover, to its feasibility of PHysBook it is will be uploading to Google Playstore.

Research Questions

To meet the needs of schools and become the latest in this research, an e-pocket book-assisted learning innovation was prepared using the PBL model for high school students. Hence, this research raises the following inquiry:

(1) How to implement the PBL learning model assisted by PHysBook to improve students' CTS?
(2) How to improve students' CTS with the PBL learning model assisted by PHysBook?
(3) How do students respond after implementing PBL assisted by PHysBook to improve students' CTS?

Literature Review

The Rational Between Learning Theory, PBL Models, and CTS Indicators

One of the abilities that supports each of these 3 HOTs is CT. It follows that mastering CT is a prerequisite to learning the remaining 3 HOTs processes (Satriawan et al., 2020). CTS have been integrated into the Indonesian school curriculum since the introduction of the 2013 National Curriculum and continue to be part of the Curriculum Merdeka (Afdareza et al., 2020; Pahrudin et al., 2021; Tyas et al., 2019). CTS students will make an effort to use logical thinking to comprehend and make difficult decisions, as well as to see how various systems are interconnected (Saputri et al., 2019). Physics lessons provide pupils the opportunity to build the 4C's (Aliftika & Utari, 2019; Khotijah et al., 2019).

The four indicators in CT and problem taking process are interpretation, analysis, evaluation, and inference (Facione, 2020; Seventika et al., 2018). Using present-day technology as an instructional tool in conjunction with real-world difficulties experienced in daily life is one method of enhancing CTS, according to established educational theories (Antón-Sancho et al., 2023; Damayanti & Kuswanto, 2021; Wibowo, 2023; Wijayanto et al., 2023). Based on research by Ardianti et al. (2022) states that the the PBL model is supported by several foundational learning and developmental theories. Piaget's Individual Constructivism Theory emphasizes that learners build knowledge through personal experiences, while Vygotsky's Constructivist Social Learning Theory highlights the importance of social interactions and cultural context. PBL aligns with Bruner's Discovery Learning Theory by encouraging exploration and inquiry, and with Ausubel's Theory of Meaningful Learning by integrating new knowledge with existing cognitive structures. John Dewey's Theory of experiential learning is reflected in PBL's emphasis on engaging students in real-world problems and active participation. The relationship between learning theory, PBL syntax, and indicators of CTS is as in Table 1.

Table 1

The relationship of learning theory, PBL syntax, and CT indicators

Learning Theory		Syntax of PBL	CT Indicators
Piaget Piaget saw that the process of constructing knowledge is carried out through assimilation and accommodation.	Dewey Teachers should provide assignments with a problem-solving focus and assist students in researching social justice and intellectual significance. Bruner Encourage students to select, retain and change information effectively by encouraging students to have hands-on learning experiences and conduct their own experiments for them to discover principles for themselves.	Phase 1 Orient students to problems.	Interpretation In this case, giving impressions, opinions, or views on something is a problem given to learners.
		Phase 2 Organizing learners on problems.	Analyze Linking the information obtained with concepts and solving strategies.
Vygotsky Although students are still involved in active learning, educators must actively guide every student's activity. Ausubel Assimilate new knowledge into learners' preexisting cognitive systems.		Phase 3 Support instructors' individual or group research projects.	
		Phase 4 Learners create and showcase demonstrations and artifacts.	
		Phase 5 Examine and assess the process of solving problems.	Evaluation Review or review each troubleshooting step or identified information.
			Inference Make conclusions by attaching supporting evidence and explaining reasoning with logic.

PHysBook (Pocket Physics E-Book)

In this study, a media was implemented that helped in the process of implementing PBL in the classroom. The media is in the form of an application-based computer program with the name PHysBook or stands for Pocket Physics E-Book. The specifications of PHysBook development are as in Table 2.

Table 2

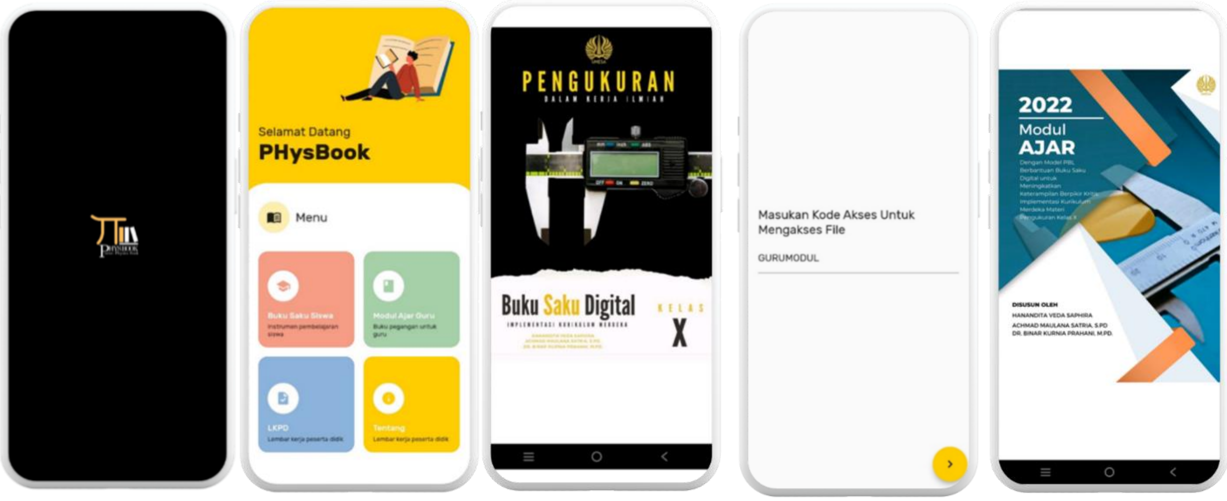
Specification of PHysBook

App Name	PHysBook	Language	:	Indonesia
File Size	< 100 MB	Operating systems	:	Android
Link Download	unesa.me/PHysBookApk	Minimum Version	:	*Nougat* (Android 7.0)
Application features	1. Home start 2. A pocket book of materials 3. Teaching modules for teachers 4. Students Worksheet 5. Developer info			

The use of mobile-based Android as a learning medium has become one future technology with high flexibility (Prahani et al., 2022). Moreover, research by Hidayatulloh et al. (2020) the development of STEM-based textbook has a validity score of 3.70, categorizing it as very valid. Additionally, the increase in students' classical problem-solving skills was 0.75, placing it in the high category. Furthermore, the percentage of students achieving completeness in problem-solving skills tests is 90%, indicating that STEM-based textbooks are effective in enhancing students' problem-solving skills. In line with this, Kaukaba et al. (2022) developing "ABC - Acid & Base Chemistry" android mobile learning media that is valid, practical, and effective in improving students' learning outcomes and motivation. The initial display and initial homepage in this application are as in Figure 1a.

Figure 1

PHysBook start and home view



(1a) (1b) (1c) (1d) (1e)

If the user selects the student pocketbook sub-menu, a student pocketbook presentation will appear as in Figure 1b. Figure 1c shows *Student Pocketbook Sub-Menu To 'Pengukuran' (Measurement) Material.* If the user, especially the teacher, a presentation will appear to enter the access code so that students cannot access it freely. Previously, teachers would be assigned an access code. After typing the access code, namely *'GURUMODUL'* as in Figure 1d then a presentation of teaching modules will appear as shown in Figure 1e. Figure 1e shows *Teacher Teaching Module Sub-Menu Display After Access Code Successfully Entered.*

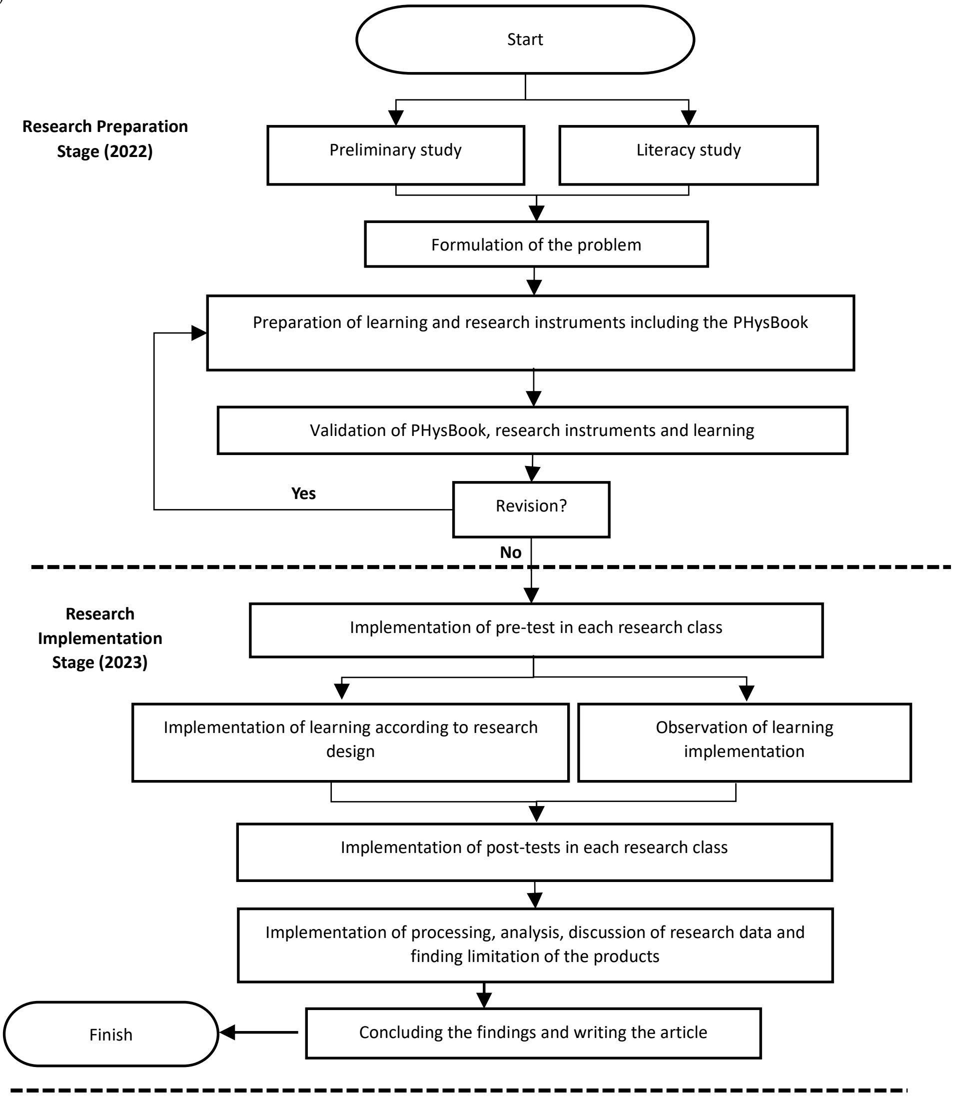
Methods

This quantitative descriptive research method details the application of the PBL model with PHysBook support. The study follows a true experimental research (TER) with a randomized control group O1 and O2 design (Jatmiko et al., 2018). TER design research uses comparison or control groups to obtain definite results after treatment in a particular class (Nisa & Hariyono, 2019). Furthermore, research flowchart is likely in Figure 2.

The implementation process including 14x45 minutes course hours in total and 2x45 minutes in each learning, with PBL model that including theories of Piaget's Individual Constructivism Theory, Vygotsky's Constructivist Social Learning Theory, Bruner's Discovery Learning Theory, Ausubel's Theory of Meaningful Learning and John Dewey's Theory (Inayati, 2022).

Figure 2

Research flowchart



Population and Research Sample

The study population is a subject or object with specific qualities and characteristics within the generalization area set by the researcher from whom conclusions are drawn. The research sample was taken based on the formulation by Slavin in equation (1) with an error tolerance (e) is 5.00%.

$$\text{Sample} = [\text{Population} / (1 + e^2 \text{ x Population})] \quad (1)$$

(Jatmiko et al., 2018)

Thus, from 140 population students in this study, 104 samples of students were obtained, which will be used as research samples. Each class will be given an O1 as the initial stage of research. The pre-test (O1) is carried out so that researchers can analyze students' initial skills against critical thinking indicators. Then, applying the PBL model assisted by PHysBook will be applied to experimental class 1 (X1). While experimental class 2 (X2) will be applied learning with a PBL model but using PowerPoint media. For comparison, the conventional class (C) was enforced using the lecture method. In conventional classes, the learning process is carried out without unique learning models or media from researchers. After implementing these learning treatments, each class will be given a post-test (O2) to measure final CTS after classroom learning with specific models and media (Khoiri et al., 2021).

Learning and Research Instrument

This research uses learning tools to support the implementation of research, namely teaching modules, Student Worksheets (SW), and PHysBook. The research tools employed in this investigation include observation forms for monitoring the learning process and assessing CTS, alongside observation sheets and questionnaires to gauge student responses. The observation sheet for learning implementation and CTS is an assessment sheet filled out by one class teacher and two students designated observers to observe researchers during the learning process in class.

A learning tool is said to be suitable for use if it has gone through a validation and reliable assessment process. Learning devices and instruments are validated by selected lecturers at the Department of Physics, Surabaya State University. The devices that must go through the validation stage before use are teaching modules, SW, and PHysBook. Then, the research instruments that go through the validation stage are critical thinking test sheets, observation sheets on learning implementation and CTS. In order to ascertain the validity criteria of produced items and technologies, data on the outcomes of validity evaluation are conducted through descriptive analysis (mean) on the significance of the approach of each feature. Furthermore, Cronbach Alpha values are employed to assess the dependability of technologies and goods using validity result data (α).

Device validation is carried out by three expert lecturers as validators. The assessment range is between 1–4 with criteria (1) very poor, (2) poor, (3) good, and (4) excellent. The validation results and reliability of learning tools and research instruments are showing that the average validation mode value for 8 aspects of assessment in experimental class 1 teaching module is 3.14 or with valid categories. It was concluded that the teaching module in experimental class 1 was suitable for use. The average validation score for 8 aspects of assessment in the experimental class 2 teaching module is 3.25 or with a very valid category. It was concluded that the teaching module in experimental class 2 is worth using. Experimental media validation sheet 1 in the form of the PHysBook application which was assessed by validators with 19 aspects of learning media both the feasibility of content, language and presentation of 3.53 with very valid categories. The average value of validation mode for 19 aspects of assessment in experimental class 2 learning media in the form of power points is 3.42 with a very valid category. It was concluded that the learning media in both experimental classes were feasible to use. Further analyzed shows that the SW validation sheet consists of 18 aspects that will be assessed by validators in terms of format, language and content, the average validation mode value for 18 aspects of assessment in SW is 3.44 with a very valid category, so it is concluded that SW is feasible to use.

The question instrument validation sheet consists of two aspects in terms of content and language for each indicator of CTS. For each of the three research courses, pre- and post-test question forms were utilized. The average value of the validation mode is 3.19 with valid categories, so it is concluded that the question instrument is suitable for use. The validation sheet of the teacher activity observation sheet consists of 10 aspects of objectives, learning elements and language. The average validation mode value is 3.70 with a very valid category. The results of the student activity observation sheet showed an average validation mode value of 3.70 with a very valid category. It was concluded that the observation sheet of student activities was suitable for use.

In the study, reliability testing was carried out to determine the level of stability or accuracy of an assessment. The reliability of a learning device and instrument is measured using SPSS software. Learning aids and research equipment are regarded to be trustworthy if 0.60 ≤ ≤ 1.00 and unreliable if $\alpha < 0.60$ (Jatmiko et al., 2018). Assess the reliability of each learning tool and research instrument. Reliability is calculated using SPSS with regard to decision making. Experimental teaching module 1 has a value of 0.72 with a high category based on intervals. Experimental teaching module 2 has 0.61 with medium category. Experimental media 1 and experimental media 2 each have values of 0.75 and 0.72 with high categories. SW is rated at 0.74, indicating high reliability. The research instruments, including pre-test and post-test sheets, score 0.66, signifying a medium level of reliability. The response questionnaire achieves a reliability score of 0.83, classified as high. The observation sheets for both teachers and students score 0.78 and 0.77, respectively, falling within the high reliability range. In summary, all utilized learning tools and research instruments are considered reliable.

Data Analysis Techniques

Observational Analysis of Learning Implementation and CTS

Data analysis on the results of this observation aims to determine the implementation of a learning process carried out in experimental and control classes using the PBL model assisted by PHysBook with observers of one physics teacher and two physics education students. The analysis learning implementation carried out by observers is analysed using equation (2) with category intervals in Table 3.

$$\text{Response (\%)} = \frac{\text{Total Score}}{\text{Ideal Score}} \text{x100} \qquad (2)$$

Table 3
Learning success rate interval

Learning Implementation Achievement	Category	Learning Success Rate	Learning Implementation Achievement	Category	Learning Success Rate
3.50 – 4.00	Excellent	Success	1.50 – 2.49	Moderate	It did not work
2.50 – 3.49	Good	Success	0.00 – 1.49	Less	It did not work

Analysis of Improving Learners' CTS

Learners' CTS can be measured in writing using O1 and O2 scores. Learners' O1 and O2 scores were analyzed using difference tests and N-gain analysis. Prior to the disparity test, the homogeneity testing and a normal distribution test are used to ascertain whether O1 and O2 are from a homogenous population and have a normal distribution. The N-gain criteria are based on Adilla & Jatmiko (2021) and Wardani & Jatmiko (2021) that $\langle g \rangle < 0.30$ is low criteria, $0.30 \leq \langle g \rangle < 0.70$ is in moderate criteria, and $\langle g \rangle < 0.70$ is in high criteria. Effect size is a value that measures the intensity of a population's link between two variables or a sample-based calculation for that amount. In this study, the effect size was calculated based on Cohen's d with intervals of 0.00 – 0.20, Very Low, 0.21 – 0.5 Low, 0.51 – 1.00, Moderate and > 1.00 Strong (Lestari et al., 2021b; Prahani et al., 2022,). Cohen's d concludes that the greater the value, the more significant the difference between the control and experimental groups (Goodman et al., 2019).

Analysis of Student Response Questionnaire Sheets

Positive and negative comments are applied equally in the Likert Scale evaluation of responses from pupils surveys. Then, convert the percentage of learner response values into categories, 0.00 – 19.00, Very lacking; 20.00 – 39.00, Lack; 40.00 – 59.00, Moderate; 60.00 – 79.00, Good; 80.00 – 10.00, Excellent (Lestari et al., 2021a).

Findings

Analysis of the Implementation of the PBL Learning Model Assisted by PHysBook

Teacher Activity

Teacher activities during learning are observed and assessed to determine the suitability of teacher activities with the stages of the PBL model and the media that have been implemented. Data from the analysis of observations of teacher activity are shown in Table 4.

Table 4

Results of the assessment of observations of teacher activities

No.	Assessment Aspect	Average	Percentage	Category
Opening				
1	The teacher opens the learning with greetings, prayers, giving receptions, and delivering learning steps.	4.00	100.00	Excellent
Phase 1				
2	The teacher provides a stimulus regarding the importance of measurement.	4.00	100.00	Excellent
3	The teacher gives a problem and asks students to give an initial interpretation.	4.00	100.00	
Phase 2				
4	The teacher asks students to form groups of 4-6 people and then distribute SW.	4.00	100.00	Excellent
5	Teachers provide opportunities for learners to analyze problems and get relevant information related to the material.	4.00	100.00	
Phase 3				
6	Teachers guide students to collect data or explore problems assisted by PHysBook.	3.67	91.67	Excellent
7	The teacher guides students to analyze the results of their group discussions related to the problems presented at SW.	4.00	100.00	
Phase 4				
8	The teacher guides the learners to make an inference from the solution they find.	3.67	91.67	Excellent
9	The teacher asked each group to present the results of their discussion through a presentation.	3.00	75.00	Good
Phase 5				
10	Teachers facilitate class discussion activities related to inter-group evaluations that present the results of their discussions.	4.00	100.00	Excellent
11	The teacher confirms the results of the class discussion.	4.00	100.00	
12	The teacher asks students to provide final inferences on the learning process that has been carried out.	3.67	91.67	
Closing				
13	Teachers provide opportunities for students to ask questions about what they still need to understand.	4.00	100.00	Excellent
14	The teacher ends the lesson by praying and greeting and thanking.	4.00	100.00	
Average		3.86	96.43	Excellent

Table 4 indicates that the mean value derived from the assessments of the three observers is 3.86. The analysis of teacher activity observations yields an average percentage of 96.43%, falling into the "very good" category. Considering the average scores and percentages from the three observers, it is evident that nearly all phases and components of the teaching module are executed exceptionally well during the learning process.

Student Activities

Student activities during learning are observed and assessed to determine the suitability of teacher activities with student activities to the stages of the learning model PBL assisted by learning media to train CTS of student activities are shown in Table 5.

Table 5

The results of observational activities of learners with indicators of CTS

Class	Average	Score	Category
X1	3.53	88.30	Excellent
X2	3.20	80.00	Good
C	2.44	60.89	Moderate

Overall, the evaluation of CTS in X1 yielded an average score of 3.53 out of a possible 4.00, signifying that student involvement in learning through the PBL model with PHysBook support falls within the excellent range. X2 achieved a score of 3.20, categorizing it as good, while the C class obtained an average score of 2.44, which is considered moderate.

Analysis of Learners' CTS Improvement with the PBL Model Assisted by PHysBook

Test Prerequisites

Prerequisite testing is fundamental for establishing which test statistics are required, whether the test uses parametric or non-parametric statistics. Normality tests were performed on O1 and O2 scores using Kolmogorov-Smirnov. Table 6 is the result of a normality test using Kolmogorov-Smirnov with SPSS. Table 6 shows that each class's normality test results in the O1 and O2 have a sig value. < 0.05 so that H_0 is rejected. It was concluded that the data was not normally distributed. Homogeneity test used based on Levene.

Table 6

Findings of normal distribution testing with kolmogorov-smirnov in SPSS

Classes	Kolmogorov-Smirnov[a]			Shapiro-Wilk			Hypothesis
	Statistic	df	Sig.	Statistic	df	Sig.	
O1 X1	0.21	35.00	0.00	0.88	35.00	0.00	H_0 rejected: Data is not normally distributed
O2 X1	0.16		0.02	0.83		0.00	
O1 X2	0.21		0.00	0.88		0.00	
O2 X2	0.17		0.01	0.91		0.01	
O1 C	0.19		0.01	0.88		0.00	
O2 C	0.26		0.00	0.86		0.00	

Table 7

O1 and O2, homogeneity test results, based on the mean

	Levene Statistic	Sig.	Hypothesis
O1	2.26	0.10	H_0 accepted: Data homogeneous
O2	2.70	0.07	

Table 7 shows that the homogeneity test results on the O1 based on the mean have a sig value. > 0.05 which is 0.10 > 0.05 so that H_0 is accepted. It was concluded that the data were homogeneously distributed for O1 assessment. Table 7 indicates that the homogeneity test result on the O1 based on the mean has a Sig value. > 0.05 i.e. 0.07 > 0.05 so that H_0 is accepted. It was concluded that homogeneously distributed data for O2 assessment.

Improved CTS of Learners

Several assessments were carried out to measure the impact of the educational tool on students' CTS in every research groups. The data proved abnormally distributed; the difference test analysis used the Wilcoxon non-parametric test. The results of the Wilcoxon difference test in each class did not show a decrease from O1 scores to O2 scores; this was seen based on the negative rank values in each class showing 0.00 results.

Table 8

Comparison of Average O1 and O2 Scores of CTS Indicators In Each Research Class

Classes	X	Interpretation (1)	Analysis (2)	Inference (3)	Evaluation (4)
X1	O1	0.80 (L)	0.51 (L)	0.40 (L)	0.06 (L)
	O2	8.89 (H)	8.43 (H)	7.31 (H)	6.40 (H)
X2	O1	1.54 (L)	0.69 (L)	0.23 (L)	0.06 (L)
	O2	3.43 (L)	1.91 (L)	0.29 (L)	0.11 (L)
C	O1	0.71 (L)	0.66 (L)	0.51 (L)	0.26 (L)
	O2	1.69 (L)	1.80 (L)	0.66 (L)	0.91 (L)

Note. L is Low category and H is High category

Based on Table 8 Interpretation indicators have the highest value from both O1 and O2 scores, while evaluation indicates CTS with the lowest value. The N-gain test was conducted to determine and analyse the level of improvement in students' CTS after being given learning treatment. Table 9 is the result of the N-gain calculation based on SPSS.

Table 9

N-gain and effect size results

N-gain			Effect Size		
Classes	Statistic	Category	Class	Effect Size	Category
X1	0.78	High	*X1-X2*	0.80	Moderate
X2	0.13	Low	*X1-C*	0.76	Moderate
C	0.10	Low	*X2-C*	0.40	Low

Table 9 shows that the N-gain result for X1 was 78.87 in the high category. X 2 showed a known N-gain of 13.91, while for the C class, an N-gain of 10.39. It was concluded that X 2 and C classes in the N-gain category were low. Furthermore, the effect size was calculated based on Cohen's d. Table 9 is the result of calculating the effect size value. Furthermore, Table 9 shows that the difference in effect between X1 and X2 is 0.80 with the medium category. The difference in effect size for experimental class 1 and control is 0.76 with the moderate category. X2 with C class has an effect size ratio 0.40 in the low category.

Analysis of Learner Responses After the PBL Model Assisted by PHysBook Implementation to Improve Learners' CTS

The student response questionnaire sheet applied to this study consists of 10 statements that will be assessed by each student in X1, X2, and C classes using per-item analysis with the Likert scale. Table 10 is the result of a student response questionnaire.

Table 10

Results of student response questionnaire

Statement	Students' response (%) (n=104)			
	1	2	3	4
S1	0.00 (0.00)	11.76 (4.00)	32.35 (11.00)	55.88 (19.00)
S2	41.18 (14.00)	58.82 (20.00)	0.00 (0.00)	0.00 (0.00)
S2	2.94 (1.00)	14.71 (5.00)	41.18 (14.00)	41.18 (14.00)

Discussion

Analysis of the Implementation of the PBL Learning Model Assisted by PHysBook

Observations are carried out according to the phase of the learning model applied in each research class. X1 and X2 have 14 assessment aspects in 5 phases of PBL. The opening and closing of the lesson also complement the assessment aspect. Observation of learning is carried out for 2x45 minutes in each learning meeting. At the opening stage, the teacher applied greetings, prayed, gave perceptions, and conveyed learning steps before starting learning (Anggraeni et al., 2023). Perception helps teachers attract students' attention and provide focus and attention to students so that learning begins immediately (Molloy et al., 2020; Qadir & Al-Fuqaha, 2020; Wolff et al., 2021).

Table 4 Showing phase 1, getting an average score in the very good category. Phase 1 has aspects of teacher assessment, provides stimulus about the importance of the material and provides a problem, and asks students to provide initial interpretation. Phase 1 of the PBL model has one indicator of CT: interpretation. Interpretation asks students to give impressions or opinions and initial views on the problems given by the teacher (Amin et al., 2020).

Observations in phase 2 show that the results of the assessment of teacher activity observations in Table 4 showed that phase 3 was carried out very well. In this phase, the indicator of CTS implemented is analysis. The analysis is performed to acquire data gathered from the issues that are supplied and while working on SW (Martawijaya et al., 2023; Suryawati et al., 2020). In line with this, the assessment of observations of student activities on the analysis indicators is in the very good category in X1 and X2. The C class had an assessment of learner activity in the sufficient category.

Phase 4 is the teacher's activity to guide students to make an inference from the solution of physical problems in everyday life that they have found and present their artifacts or findings through presentations carried out very well. In phase 5, the teacher's activity, namely facilitating class discussion activities and forming an evaluation and final inference on learning, was carried out very well. In both phases, students can make conclusions about what they have found as a solution to physical problems in everyday life with the help of PHysBook.

Table 4 also shows that the closing activities are carried out very well. At this stage, the teacher provides opportunities for students to ask questions related to what they do not understand to avoid misconceptions. In this aspect, the teacher ended the lesson by praying and saying greetings and thanks. Final learning sessions are necessary to give inferences from studying activities and confirmation of answers to physics issues in real life that pupils have provided during class through presentations (Monica et al., 2020).

Table 5 demonstrate an assessment of student activity with indicators of CTS in X1 in the excellent category. Learners successfully meet the assessment of each aspect of learning in each indicator of CTS. X2 is in a good category, in order that learners still need help with inference indicators. When making presentations, learners need help to conclude the solution to the problem they make based on the analysis. In line with this, the assessment of student activity in the control class has sufficient categories. This is because the learning model used by the C class still uses a conventional model in the form of lectures, so in each indicator of CTS, students still need help conveying initial opinions, analysing, evaluating, and inferring. This problem is continuous with students who are not trained in CTS in the physics learning process, and no learning media supports learning (Koes-H et al., 2023). However, based on the Table 5, X1 had the highest student activity observation value compared to X2 and C classes.

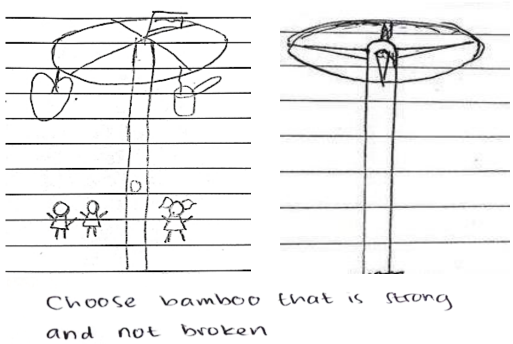
Analysis of Learners' CTS Improvement with the PBL Model Assisted by PHysBook

Improvement of CTS is carried out using O1 and O2 research instruments. Each O1 and O2 consists of two questions, including indicators of CTS, O1, and O2 instruments were given to the entire research class. O1s are given before the researcher conducts treatment. O2 is given after researchers treat learning using certain media-assisted models. O1 and O2 research instruments have the same questions. Before the analysis of improving CTS, O1, and O2 data were tested using prerequisite tests, namely normality tests and homogeneity tests.

Test normality using Kolmogorov-Smirnov with SPSS in Table 6 states that H_0 is rejected or the data is not normally distributed. This is because the samples used are more than 30 samples or include big data, so the tested data is not normally distributed (Orcan, 2020). Furthermore, the homogeneity test, which aims to determine whether the assumption of homogeneity in each criterion has been achieved (Ilkorucu et al., 2022; Muhfahroyin et al., 2023, 2024). Based on Table 7 the homogeneity test result using the Levene test is H_0 received or homogeneously distributed. Statistically, the measured population must be homogeneous for the measurement results to be valid and accurate (Clark et al., 2019; Sürücü, 2020).

Figure 3

Learners' O1 Answers on Interpretation Indicators



The analysis continued with a difference test using a non-parametric Wilcoxon test because, based on prerequisite tests, the data was not normally distributed. Wilcoxon is a non-parametric test to measure the significance of the difference between 2 groups of data in pairs of ordinal or interval scales but abnormally distributed (Budiono & Prasetia, 2022). The results shows that H_0 is accepted or there is a difference between CTS from O1 and O2. The difference is in the form of an increase in students' CTS. Based on the CTS of each class, it can be analysed based on indicators with the highest to lowest scores. Figure 3 is the average of O1 and O2 scores of CTS indicators. Interpretation is an indicator with the highest value in terms of O1 and O2.

Figure 3 is an example of an answer to a question to provide an interpretation (opinion) in the form of a design drawing and size of the areca nut climbing frame of the three students during the O1. The answers given by students still need to be detailed and appropriate. Students only describe the frame of *panjat pinang* (a competition carried out by climbing an areca tree) without providing details of the size of the initial plan of climbing the areca nut. One of the students also only wrote an opinion without a significant solution to the existing problem. Learners struggle due to the must have a deeper understanding of the idea and the problem information (Abidah et al., 2020). This causes the value on the interpretation indicator on the O1 to be still in the low category. However, compared to other indicators, interpretation has the highest value. Because many learners still answer to interpretation indicators, this is in line with the research of Basri et al. (2019), which concludes that interpretation indicators have a higher category than other indicators of CTS, such as evaluation and analysis. Refer to Figure 3 The value of the interpretation indicator on the O2 increased to the high category. There are examples of students' answers during the O2, as in Figure 4.

Figure 4

Learners' O2 answers on interpretation indicators

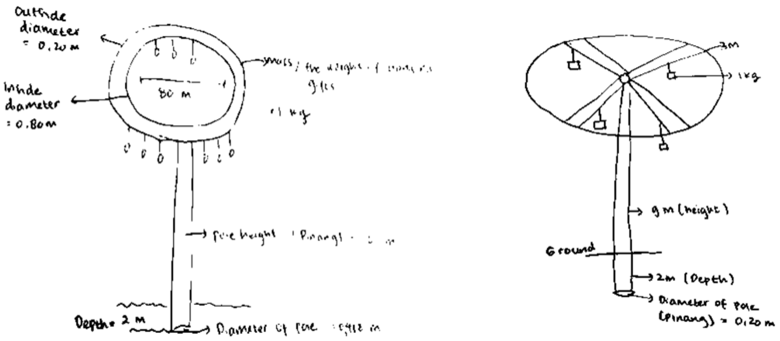


Figure 4 shows that learners have successfully written answers to the requested aspects. After learning, students have understood the terms value, unit, and magnitude. This causes the score on the O2 to increase. Based on Table 8 the second highest indicator is analysis. Students are asked to analyse measuring instruments that can be used to make areca nut climbing frames that they have made. Students are also asked to write down the measured quantity, type of quantity, and unit on the tool, but during the O1, students only give a blank table with answers, as in Figure 5.

Figure 5

Learners' O1 answers on analysis indicators

Gauge name	Measured quantity	Type of magnitude	SI	Dimention
meter roll				

Most of these students need to explain how they will analyze the use of measuring instruments. Thus, students' answers must still meet a logical, systematic, and complete assessment. This discovery aligns with research by Saphira & Prahani (2022), which states that most students must explain how to model the problem in the analysis indicators. Students also do not add analysis based on the results of calculations they have done. The rise in CTS also showed up in the analysis indicators. The implementation of learning causes the value of the analysis indicator to increase from the low category to the high category. Figure 6 is an example of students' answers to analysis indicators during the O2.

Figure 6

Learners' O2 answers on analysis indicators

Gauge name	Measured quantity	Type of magnitude	SI	Dimention
meter roll	length	meter	meter	[L]
Balance scale	Mass	kilogram	kilogram	[M]
Vernier Caliper	length	meter	meter	[L]
Screw Micrometer	length	Meter	meter	[L]

Based on Figure 6 Students have successfully named several measuring instruments that they will use when realizing their design, along with magnitudes, units, and dimensions. Students have met the assessment criteria on the analysis indicators, so there is an increase in CTS in the analysis indicators during the O2. The next indicator is inference. Inference indicators ask learners to make inferences from what they have designed regarding the solution to the problem presented (Prahani et al., 2023). Figure 7 is the learner's answer to the inference indicator during the O1.

Figure 7

Learners' O1 answers on inference indicators

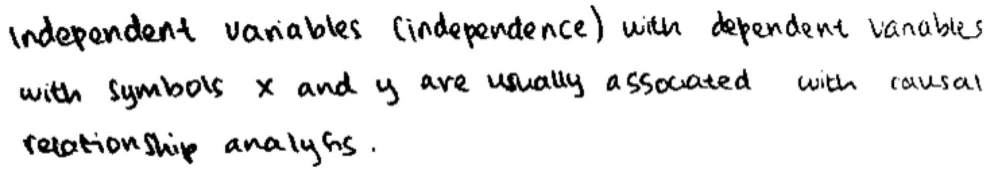
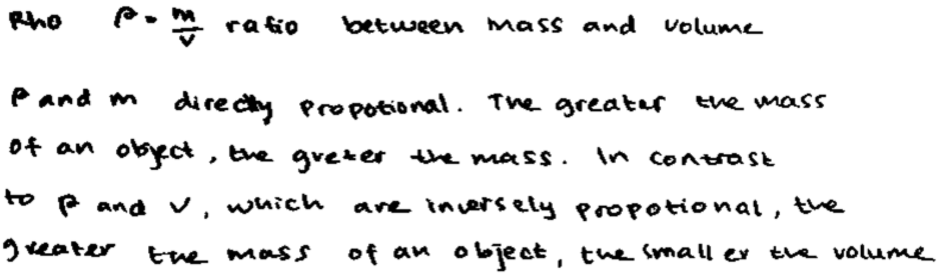

independent variables (independence) with dependent variables with symbols x and y are usually associated with causal relationship analysis.

Figure 7 is a learner's O1 answer on inference indicators. One of the questions on inference indicators is to provide conclusions about the relationship of each variable on density. Based on Figure 7 the answer does not match what is requested. This causes the scores of the O1 students to be in the low category. Improvement of CTS in inference indicators also occurs based on Table 8. As for O2 answers on inference indicators, as in Figure 8.

Figure 8

Learners' O2 answers on inference indicators


Rho $\rho = \frac{m}{v}$ ratio between mass and volume

ρ and m directly propotional. The greater the mass of an object, the greter the mass. In contrast to ρ and V, which are inversely propotional, the greater the mass of an object, the smaller the volume

Figure 8 shows that learners have been able to mention the relationship between variables in density based on the results of observations in the previous point. This causes the O2 value on the inference indicator to increase. The next indicator is the evaluation indicator, which has the lowest value among the four indicators of CTS, based on Table 8. The student's answers on the evaluation indicator at the time of the O1 are blank, so the O1 score on the indicator has an average of 0.12. Examples of student answers as in Figure 9.

Figure 9

Learners' O1 answers on evaluation indicators

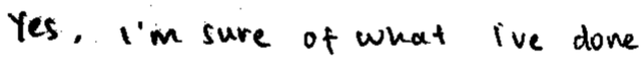

Yes, I'm sure of what I've done

Figure 9 is a learner's O1 answer on the evaluation indicator. Students are asked to provide reviews related to what they have worked on. Evaluation indicators are indicators that students need to answer. Figure 9 is one of the answers filled in by students, but there is no further review of deficiencies or specific reviews related to the solutions they have described. Based on Table 8 however, evaluation indicators still have an increase in value after the O2. Figure 10 is the answer from students to the evaluation indicators during the O2.

Figure 10

Learners' O2 answers on evaluation indicators

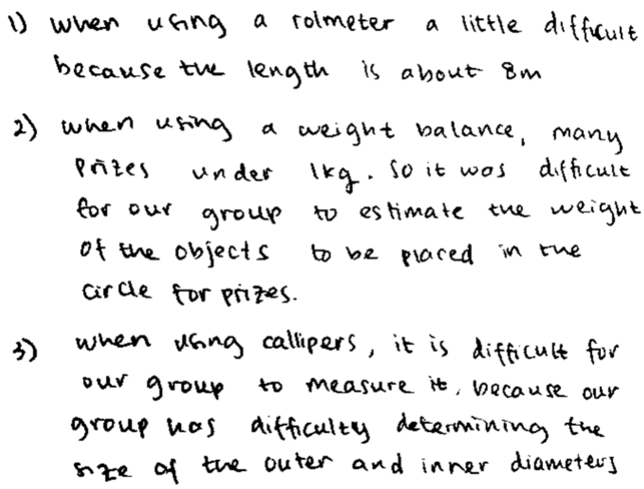

1) when using a rolmeter a little difficult because the length is about 8m
2) when using a weight balance, many prizes under 1kg. so it was difficult for our group to estimate the weight of the objects to be placed in the circle for prizes.
3) when using callipers, it is difficult for our group to measure it, because our group has difficulty determining the size of the outer and inner diameters

Figure 10 illustrates that students effectively identified challenges encountered while designing the areca nut climbing frame. They displayed critical thinking by recognizing the difficulty of measuring an 8.00-meter length of bamboo with a roller meter. Consequently, there was an enhancement in CTS in the evaluation indicators during O2. To determine the extent of CTS improvement, an N-gain test was performed using SPSS. Table 9 reveals that the increase in CTS was rated as high for X1, and low for both X2 and the C class. Accordingly, the most substantial CTS improvement occurred in X1 following the implementation of the PBL model assisted by PHysBook. The next step involves an effect size analysis, which aims to gauge the strength of the relationship between two variables in a population or sample through the estimation based on Cohen's d (Lestari et al., 2021b; Prahani et al., 2020). Based on Table 9 shows that the difference in effect between X1 and X2 with the moderate category. This shows that the treatment of the PBL model assisted by PHysBooks has a more influential field operational impact on improving students' CTS.

Analysis of Learner Responses After the PBL Model Assisted by PHysBook Implementation to Improve Learners' CTS

Student response data is obtained from student response questionnaires filled out after the learning process through Google Forms. Based on Table 10 as many as 44.12% of students did not agree that physics subjects were boring. Furthermore, 55.88% of students strongly agree that learning physics using PHysBook is fun and can be an innovation in classroom learning, and 58.82% of students disagree with the negative statement of using digital pocketbook-assisted PBL models in learning boring physics. Based on the results of interviews with several students, it was stated that:

I am interested in learning Physics, especially using interesting learning media such as PHysBook, as well as fun classroom activities so that Physics does not feel difficult. -Fs

Previously, physics lessons were troublesome and difficult to understand because learning only listened, but after learning to use applications and activities in class, I became interested in physics. My rational thinking about physics is getting more and more open. -Rz

Hence, it response also match with the other preliminary studies, it is stated that using this e-pocket book can be one of the alternative learning media that attract the interest and attention of students. In the following statement, all three research classes disagreed with the negative statement that CTS is not necessary for physics learning. Statements related to the use of digital pocketbook-assisted PBL models can improve CTS, all three classes agreed. In line with this, the implementation of the PBL model assisted by PHysBook to improve CTS has a good response from students so that it can be used as an innovation in learning.

Conclusion and Implications

The implementation of the PBL learning model with the help of PHysBook was successfully implemented with a very good category. Learners successfully meet the assessment of each aspect of learning in each indicator of CTS. Learners still need help with inference indicators. In line with this, the assessment of student activity in the control class has sufficient categories—the value of observation of student activities on CTS in the high category. There is a difference between O1 and O2 in class with the PBL model assisted by PHysBook in improving CTS with an increased rate in the high category with strong effect scores. Based on the research problem's limitations, this study's drawback is that the research subject is limited to PHysBook-assisted in the measurement of physics material with an operating system (OS) Android only as a representative of improving CTS. To broaden the applicability and impact of the findings, future research should explore other educational contexts, operating systems, languages, and physics materials. Researchers can extend the study to different schools or educational levels to compare results and measure CTS improvements using PHysBook. Furthermore, developing the application for other operating systems and in multiple languages could enhance its usability and effectiveness. Future research should also consider implementing or developing new approaches on other physics materials to measure additional skill variables. These expansions will provide more detailed implications for practice and offer specific areas for future research based on the study's limitations and findings.

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