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Integrating OLabs in Problem-Based Hybrid Learning: Effects on Higher Order Thinking Skills

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Abstract – *This study was motivated by the low levels of student engagement and higher-order thinking skills (HOTS) observed in a preliminary investigation at State High School 1 Talaga, exacerbated by limited laboratory resources that hindered effective learning. The research aimed to explore the effect of a Problem-Based Hybrid Learning (Pro-BHL) model, supported by OLabs (Online Laboratory), on improving students' HOTS, specifically in the topics of heat and heat transfer. A quasi-experimental design with a posttest-only control group was implemented, involving 244 students from 7 classes. Through purposive sampling, the study selected class XI MIPA 3 as the experimental group and XI MIPA 2 as the control group. HOTS was measured via an essay-based posttest, addressing analysis (C4), evaluation (C5), and creation (C6) indicators. The results, analyzed using a t-test at a significance level of* $\alpha = 0.05$*, revealed a statistically significant improvement in the experimental group's HOTS (tcount = 6.65 > ttable = 1.67), rejecting the null hypothesis and confirming the effectiveness of the Pro-BHL model supported by OLabs. The findings indicate that this hybrid learning model significantly enhanced students' higher-order thinking skills in the studied topics. The research highlights the potential of integrating technology like OLabs into problem-based learning frameworks, providing a scalable solution to overcome practical limitations in science education. Future research could explore integrating other virtual laboratory platforms and extending the model to different learning environments.*

Keywords: *heat; heat transfer; hots; olabs; problem-based hybrid learning*

I. INTRODUCTION

Education is a conscious and planned effort where adults provide significant guidance to enhance students' maturity, enabling them to develop their potential as resources for social life (Hidayat & Abdillah, 2019). Education plays a crucial role in the progress of a nation. An advanced nation is supported by an education system capable of developing students' abilities (Nurhayati et al., 2019; Bergin et al., 2018). In Indonesia, education is regulated by the curriculum, one of which is the 2013 curriculum.

The 2013 curriculum is a framework for learning that emphasizes the development of character and competence, aiming to form a generation with productivity, innovation, and creativity through strengthening character, skills, and integrated knowledge (Pahrudin & Pratiwi, 2019). However, many teachers still view science as a product rather than a process. As a result, science is often perceived as a compilation of factual knowledge, concepts, principles, and laws, with pedagogical approaches primarily focused on explaining these elements (Nengsih et al., 2023). This approach, while relevant to 21st-century skills, may not fully engage students in the learning process.

21st-century learning aims to optimize students' potential and shape their character for the future (Rahayu et al., 2022; Al-Kamzari & Alias, 2024). According to Boham and Domu (2021), higher-order thinking skills (HOTS) are essential for students in the 21st century, enabling them to solve real-world problems. HOTS can be cultivated through the learning process, particularly in subjects like Physics. However, the learning outcomes assessment in schools is generally based on Lower Order Thinking Skills (LOTS), and HOTS-based evaluations are still uncommon (Ernawati et al., 2023; Ubaidillah et al., 2022). HOTS are thinking skills that go beyond memorization or recall, involving higher-order skills such as analysis, evaluation, and creation based on one’s knowledge (Yulianis et al., 2019). Thus, HOTS encompasses thinking abilities at the levels of analyzing (C4), evaluating (C5), and creating (C6) (Septianingsih et al., 2022).

Nugrahnastiti and Kamaludin (2024) examined HOTS implementation in high school physics education, revealing that most teachers still rely on LOTS-based assessments. They found that the key barriers to implementing HOTS-based assessments include teachers' lack of understanding in designing HOTS questions, limited interactive learning media, and low student motivation to engage in problem-solving-based learning. This study differs from previous research by focusing on the development of HOTS questions based on contextual physics, which not only align with the 2013 Curriculum but also train students to solve real-life problems. Using a design-based research approach, the study aims to produce valid, practical, and effective HOTS questions. This approach is expected to contribute to improving the quality of physics education while addressing the challenges of 21st-century skills that emphasize analysis (C4), evaluation (C5), and creation (C6).

A preliminary study conducted at State High School 1 Talaga, involving observations, interviews with physics teachers, and initial HOTS tests on students, revealed that physics instruction was predominantly teacher-centered, with limited student engagement. Interviews with physics teachers in class XI MIPA also indicated that conventional learning, often delivered through lectures, was the most common approach, with practical experiments rarely conducted due to limited laboratory equipment. The initial HOTS test results showed an average score of

39.29%, categorized as low. In science education, developing high-level thinking skills is crucial (Alghamdi et al., 2024).

Izdihar et al. (2023) reported that students' critical thinking skills, a key component of HOTS, were relatively low. Their study employed a guided inquiry learning model with HOTS-based worksheets to enhance analytical skills (C4) and application (C3), showing positive results in improving critical thinking. Similarly, Rahayuningsih et al. (2023) found that students' critical thinking skills were still low, but the use of HOTS-based worksheets in guided inquiry learning was effective in improving their critical thinking in physics. Given the aforementioned challenges, it is evident that innovation is needed in determining an appropriate learning model to develop students' HOTS. One potential solution is to apply a problem-based learning model that centers on students. The Problem-Based Hybrid Learning (Pro-BHL) model is one such approach.

The Pro-BHL model is a hybrid problem-based learning model that emphasizes problem-solving and actively involves students in every stage of the learning process (Dalila, 2019; Chaiyasit et al., 2023). The effectiveness of the Pro-BHL model has been demonstrated in studies, such as those by Sujanem et al. (2018), which showed its effectiveness in improving students' problem-solving abilities in physics at SMA Negeri 4 Singaraja. With the rapid advancement of technology, the Pro-BHL model offers a relevant solution to adapt to modern educational environments. It provides a better understanding of the material, incorporating essential and interactive elements that engage and motivate students (Septiana et al., 2023).

To maximize learning outcomes, the application of any learning model should be supported by practical activities. Based on previous challenges, the limitations of laboratory equipment can be mitigated by using the OLabs virtual laboratory as a substitute for traditional experiments (Rahman et al., 2011). According to Wakarmamu (2022), virtual laboratory media can be integrated into various teaching strategies used by teachers in schools. The successful application of virtual laboratories has been proven in several studies. Azwar (2010) found that the Problem-Based Learning (PBL) model, when supported by virtual laboratories, contributed to improving all aspects of HOTS, including critical thinking, creative thinking, and problem-solving. Similarly, research by Muzana and Hasanah (2018) demonstrated significant improvements in learning outcomes for students taught with virtual laboratories compared to those who were not.

Selecting appropriate learning topics is essential for developing HOTS. One such topic in class XI physics is heat and heat transfer, which involves abstract concepts (Yuliana et al., 2019). Abstract physics topics are often easier for students to grasp through practical experiments (Anggraeni et al., 2011). Interviews revealed that the heat and heat transfer topics had not been practiced, either through direct experiments or virtual labs.

Therefore, this study aims to assess the effect of the Pro-BHL model, supported by OLabs, on students' HOTS in the topics of heat and heat transfer. The research aims to evaluate the effectiveness of the Pro-BHL model in enhancing students' HOTS. This study focuses on the heat and heat transfer topics in class XI MIPA at State High School 1 Talaga during the 2023/2024 academic year. By integrating problem-based learning methods with OLabs technology, this study is expected to contribute to the development of students' high-level thinking skills while addressing the challenges of 21st-century education, which demands the integration of technology and innovative approaches in teaching and learning processes.

II. METHODS

This research was conducted at State High School 1 Talaga in the XI MIPA class during the odd semester of the 2023/2024 academic year. The study population consisted of 244 students from seven XI MIPA classes. The sample selection was carried out using purposive sampling, which is a technique that selects participants based on specific criteria (Sugiyono, 2019). The aim of purposive sampling was to ensure that the experimental and control groups were homogeneous and that the distribution of data did not differ significantly. Based on this selection, class XI MIPA 3 was assigned as the experimental group, which received the Pro-BHL model supported by OLabs, while class XI MIPA 2 was assigned as the control group, which received the Direct Instruction model also supported by OLabs. This study employed a quasi-experimental design with a posttest-only control group design (Creswell, 2015).

Data were collected using two instruments: the HOTS test and the observation sheet to assess the implementation of the learning model. The HOTS test was designed to measure students' achievement of higher-order thinking skills. This test was administered after the treatment as a posttest. The HOTS aspects evaluated in this study included analyzing (C4), evaluating (C5), and creating (C6). The observation sheet was used to gather information about the implementation of the learning model in the experimental class. Data collection involved observing the teaching and learning activities in the classroom and recording them on the observation sheet. The assessment on the observation sheet covered three phases of the learning process: the introduction, core, and closing activities.

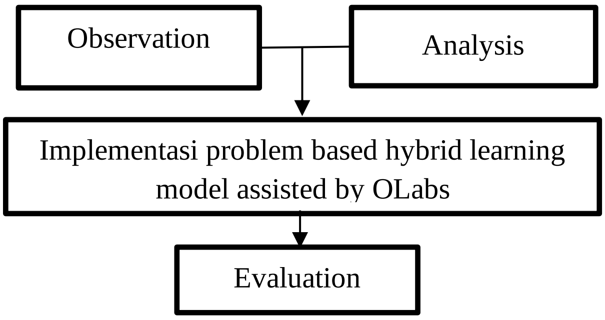

Figure 1. Research procedure flowchart

Before administering the test instruments, expert validity was conducted to ensure the reliability and appropriateness of the tools. The validity of the instruments was assessed using Aiken's V formula (Aiken, 1985). Giving validity values using Aiken's V formula is:

$$V = \frac{\Sigma s}{[n(c-1)]} \quad (1)$$

Information :

$s = r - l_0$
l_0 = the lowest validity assessment number
r = the number given by the validator
c = number of categories that can be selected
n = total number of validators

The interpretation of the V coefficient is done according to the guidelines listed in Table 1.

Table 1. Interpretation of validity coefficient

Coefficient value	**Interpretation**
$0.6 \leq V \leq 1.0$	Valid
$V < 0.6$	Invalid

(Azwar, 2010)

A trial run of the instruments was conducted on January 15, 2024, with 35 students from class XII MIPA 1 at State High School 1 Talaga. The trial aimed to determine whether the instruments were feasible for use in the research. The instrument trials included both validity and reliability tests.

Data analysis for the observations was conducted to determine whether the research instruments effectively measured what they were intended to measure, particularly in relation to higher-order thinking skills. Data collection was carried out through direct observation of student activities, such as problem-solving, explanation, and analysis. Observational data were supported by an assessment rubric specifically designed to measure HOTS indicators, including analytical skills (C4), evaluation (C5), and creativity (C6). The raw data were analyzed using the product moment correlation technique to test the validity of the instruments. If the results showed a significant relationship between the instruments and the measured indicators, the instruments were considered valid for assessing HOTS skills (Sugiyono, 2019).

$$r_{xy} = \frac{n\sum xy - (\sum x)(\sum y)}{\sqrt{\{n\sum x^2 - (\sum x)^2\}\{n\sum y^2 - (\sum y)^2\}}} \quad (2)$$

Information :

r_{xy} : correlation coefficient
x : score of each question
y : total score
n : many students

If the instrument is valid, the criteria used to determine the validity of the items are:

Table 2. Validity test interpretation

Range	Interpretation
$0.00 < r_i \leq 0.30$	Invalid
$0.30 < r_i \leq 1.0$	Valid

(Sugiyono, 2019).

Reliability testing was performed to determine the consistency of the instruments. The reliability was calculated using Cronbach's Alpha (Arikunto, 2010).

$$r_{11} = \frac{k}{k-1}\left(1 - \frac{\sum \sigma_1^2}{\sigma_1^2}\right) \quad (3)$$

Information :

r_{11} : reliability coefficient
$\sum \sigma_1^2$: sum of the variance of the scores
σ_1^2 : total score variance
k : number of items
N : number of respondents

The scores from these calculations can be interpreted into the following categories.

Table 3. Interpretation of reliability test

Range	Interpretation
$0.00 < r_{11} \leq 0.20$	Very Low
$0.20 < r_{11} \leq 0.40$	Low
$0.40 < r_{11} \leq 0.60$	Medium
$0.60 < r_{11} \leq 0.80$	High
$0.80 < r_{11} \leq 1.00$	Very High

(Arikunto, 2010).

To calculate the final HOTS score, the percentage of the total score obtained by each student was calculated based on Umami et al. (2021) is as follows.

$$P = \frac{x}{x_i} \times 100\% \quad (4)$$

Information:
P : percentage of the final score
x : score obtained by students
x_i : maximum score on one indikator

The scores obtained are then grouped according to the indicators based on the International Center for the Assessment of Higher Order Thinking listed in Table 4.

Table 4. HOTS categorization

Percentage (%)	HOTS category
0 - 20	Very Low
21 - 40	Low
41 - 60	Medium
61 - 80	High
81 - 100	Very High

(Septianingsih et al., 2022)

To assess the implementation of the Pro-BHL model, the observation data were analyzed using the Guttman scale. The percentage of the final score was calculated using the following formula:

$$\% = \frac{\Sigma Y}{\Sigma X} \times 100\% \tag{5}$$

Information :

Y : score given by students
X : maximum score

Interpretation of the percentage score of the implementation of the learning model obtained was carried out in accordance with the guidelines listed in Table 5.

Table 5. Interpretation of learning model implementation

Range	Interpretation
$0 < P \leq 20$	Very Unfavorable
$20 < P \leq 40$	Not Good
$40 < P \leq 60$	Fair
$60 < P \leq 80$	Good
$80 < P \leq 100$	Very Good

(Sugiyono, 2019)

III. RESULTS AND DISCUSSION

The research results from the implementation of the Problem-Based Hybrid Learning (Pro-BHL) model assisted by OLabs in the experimental class and the Direct Instruction model assisted by OLabs in the control class are presented in this section. At the conclusion of the learning activities, a posttest consisting of six essay questions was administered to both the experimental and control groups to measure students' HOTS scores. The posttest results are shown in Table 6.

Table 6. HOTS posttest statistics data

Posttest Score	Experiment Class	Control Class
Lowest	14.00	10.00
Highest	24.00	20.00
Maximum	24.00	24.00
Average	19.24	14.96
Variance	7.56	7.75
SD	2.75	2.62

Based on Table 6, it is observed that the mean score for the experimental class posttest was higher than that of the control class. However, the variance and standard deviation values were similar for both groups. The experimental class demonstrated a greater variance and standard deviation, suggesting that the posttest scores in the experimental class were more varied and evenly distributed compared to those in the control class.

The average percentage of posttest scores for each HOTS indicator (analyzing, evaluating, and creating) is presented in Table 7. This data highlights the differences in HOTS performance between the experimental and control groups.

Table 7. Average posttest score for each HOTS indicator

HOTS indicator	Experiment class	Control class
Analyzing (C4)	87.50%	73.21%
Evaluate (C5)	81.43%	61.43%
Creating (C6)	72.50%	54.29%
Posttest Average	**80.48%**	**62.98%**

As shown in Table 7, the average HOTS scores for the experimental class are categorized as "very good," while the control class scores are categorized as "good." Each HOTS indicator in the experimental class was higher than the corresponding indicator in the control class. This indicates that the Pro-BHL model significantly outperformed the Direct Instruction model in enhancing HOTS.

Both groups experienced a downward trend in HOTS scores from the lower-order thinking skills (C4) to higher-order thinking skills (C5 and C6). This decline is consistent with Anderson and Krathwohl's Revised Bloom's Taxonomy, which suggests that the higher the cognitive level, the more challenging it becomes to achieve a high score (Anderson & Krathwohl, 2001). Consequently, students faced difficulties when moving from lower to higher cognitive levels, which required deeper understanding and greater effort. Furthermore, the rate of change in the percentage scores for HOTS indicators in the experimental class was more gradual than in the control class. In the experimental class, the difference between the analyzing (C4) and evaluating (C5) indicators was 6.07%, while the difference between evaluating (C5) and creating (C6) indicators was 8.98%. In contrast, the control class showed a larger difference of 11.78% between analyzing (C4) and evaluating (C5), and 7.14% between evaluating (C5) and creating (C6). These results suggest that the experimental class maintained more consistent HOTS scores across the different cognitive levels.

The implementation of the Pro-BHL model assisted by OLabs was further evaluated using observer assessments to determine how effectively the learning model was applied in the experimental class. Table 8 presents the data from three observers, who evaluated the implementation of each step of the Pro-BHL model.

Table 8. Data processing of the implementation of Pro-BHL model assisted by OLabs

Syntax	Percentage	Category
Orient learners to the unstructured problem online	100%	Very Good
Organize learners to learn online	100%	Very Good
Guiding learners' investigation face-to-face	100%	Very Good
Develop and present learners' work face-to-face	100%	Very Good
Analyzing and evaluating the problem-solving process face-to-face	100%	Very Good
Average	**100%**	**Very Good**

The first syntax involves orienting learners to unstructured problems online. In this phase, students are given an online stimulus via a Telegram group. Students are then encouraged to analyze, understand, and identify strategies to solve the problem presented by the teacher. For example, the teacher may display a picture related to heat and heat transfer in everyday life and ask students to identify the associated problems. Additionally, the teacher prompts learners to respond to questions related to these issues in the Telegram group. This approach encourages students to engage actively in discussing and understanding the concepts of the topic (Dalila, 2019).

The second syntax involves organizing students to learn online. In this phase, students are tasked with working on pre-lab questions by scanning a QR code in the worksheet using their smartphones. Students complete these questions independently, which are related to the virtual laboratory activities that will follow. This phase helps students find information from various sources, understand the learning topics, and evaluate the information gathered (Rahmadani, 2019).

The third syntax involves guiding group investigations face-to-face. In this phase, students are guided by the teacher to conduct OLabs virtual laboratory activities. During these activities, students compile a problem investigation based on the results of the practicum. The experiments conducted include: (1) Newton's cooling law experiment, which determines the relationship between the temperature of a hot object and its cooling time by plotting a cooling curve; and (2) solid and liquid specific heat capacity experiments, which aim to determine the specific heat capacity of solid and liquid substances using the mixed method. This phase enables students to directly engage in experimental activities, fostering the development of HOTS (Rahmah, 2019).

The fourth syntax involves developing and presenting the results of their investigations face-to-face. In this phase, students create solutions based on the investigations they have conducted and present their findings creatively. Group representatives present the investigation results, followed by opportunities for questions and answers from other groups. This phase fosters active involvement in producing innovative problem-solving strategies, as well as expanding understanding through collaborative discussions (Rahmadani, 2019; Yustina et al., 2020). The fifth syntax involves analyzing and evaluating the problem-solving process face-to-face. Here, learners must be able to analyze the HOTS problems provided by the teacher and evaluate the results of their problem-solving efforts. This phase encourages learners to deepen their understanding of the studied topics and effectively solve complex problems through discussions with teachers and peers (Dalila, 2019).

A normality test was conducted to assess whether the data followed a normal distribution using the Chi-Square test. The results of the normality test are shown in Table 9.

Table 9. Data normality test results

HOTS Posttest Score Data	Experiment Class	Control Class
Confidence Level	99.50%	99.50%
x^2_{count}	10.01	3.61
x^2_{table}	12.80	12.80
Decision	Data is normally distributed	Data is normally distributed

Based on Table 9, it is known that the x^2_{table} value is 12.80 and each data obtained from both classes has a value of x^2_{count} which is smaller than x^2_{table}. Therefore, it can be concluded that all data groups have been taken from a normally distributed population. A homogeneity test was conducted to determine whether the HOTS test data in the experimental and control classes had homogeneous variances. The Fisher test was used for this analysis, and the results are shown in Table 10.

Table 10. Homogenity test results

HOTS Posttest Score Data	Experimental class and control class
α	0.05
F_{count}	1.09
F_{table}	1.77
Decision	H_0 accepted
Conclusion	Homogeneos

Based on Table 10, it is known that the value of $F_{count} < F_{table}$ is 1.09 $<$ 1.77, so in this case H_0 accepted and H_a rejected. Thus, it can be concluded that the variances of the posttest scores in both groups are homogeneous.

Based on the results of the prerequisite tests, it is concluded that both data groups are from normally distributed populations and have homogeneous variances. Subsequently, hypothesis testing was carried out using the independent sample t-test, and the results are shown in Table 11.

Table 11. t-test results

Data	Experiment Class	Control Class
n	35	35
Average	19.24	14.96
SD	2.75	2.62
Variance	7.56	6.88
a	0.05	0.05
t_{count}	6.65	6.65
t_{table}	1.67	1.67

Based on Table 11, it is known that the results of the hypothesis test calculation with a significance level $t_{count} > t_{table}$ is 6.65 $>$ 1.67 so that H_0 rejected and H_a accepted Therefore, at the 95% confidence level, it can be concluded that the Pro-BHL model assisted by OLabs has a significant effect on students' HOTS in the heat and heat transfer topics in class XI MIPA at State High School 1 Talaga, Majalengka Regency, during the 2023/2024 academic year.

The Pro-BHL model assisted by OLabs fosters active student involvement by providing accessibility and flexibility in learning. Through OLabs, students engage directly in physics experiment activities, both independently and in groups, where they can plan, conduct, and analyze experiments interactively (Mu'minah, 2022; Wang & Sitthiworachart, 2024). Therefore, the OLabs-assisted Pro-BHL model not only aids in the theoretical understanding of physics concepts but also enhances practical skills, promoting HOTS such as analysis, synthesis, and evaluation (Yahya et al., 2023).

In the control class, the learning process remained teacher-centered. This aligns with research by Rofiah et al. (2023) and Agustin et al. (2024), which found that the experimental class, using the Problem-Based Learning (PBL) model, outperformed the control class using the Direct Instruction model. This supports Suryadi (2022) assertion that the direct instruction model tends to make the teacher's role more dominant, resulting in one-way communication, where students heavily rely on the teacher for information.

The Pro-BHL model has been shown to significantly affect students' critical thinking skills, such as those observed in optical instrument topics (Dalila, 2019; Amin et al., 2020). In addition, the Pro-BHL model is effective in enhancing critical thinking skills at SMAN 1 Singaraja (Sujanem et al., 2018). Based on previous research, it is known that the Pro-BHL model influences critical thinking. This study confirms that the Pro-BHL model assisted by OLabs also positively affects students' HOTS, particularly in the heat and heat transfer topics.

IV. CONCLUSION AND SUGGESTION

Based on the results of the research, it can be concluded that the Pro-BHL model assisted by OLabs significantly affects students' HOTS in the topics of heat and its transfer in class XI MIPA during the odd semester of the 2023/2024 academic year at State High School 1 Talaga. The Pro-BHL model, supported by OLabs, is effective in developing students' HOTS indicators, including analyzing (C4), evaluating (C5), and creating (C6).

Based on the discussion and conclusions of this study, the following suggestions are proposed: (1) The Pro-BHL model could be integrated with other virtual laboratory activities or traditional laboratory experiments, not limited to the use of the OLabs virtual laboratory; (2) The Pro-BHL model can be implemented through other platforms such as Learning Management Systems (LMS), which have features that automatically record learners' activities in real-time; (3) The syntax of orienting learners to unstructured problems online could be enhanced by organizing online discussion sessions through video conference platforms. These sessions could provide opportunities for learners to engage in direct discussions and allow for the use of more interactive teaching materials, such as learning videos, to help learners better understand concepts; (4) For the "Creating" (C6) indicator to be categorized as "very good" in problem-solving tasks, teachers should offer more detailed explanations of the topics that students have practiced, providing clearer guidance for improvement.

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