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Improving Higher Order Thinking Skills (HOTS) Using Student Worksheets Based on Problem-Based Learning

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Abstract
Higher-order thinking skills (HOTS) are essential competencies in biology education because they enable students to analyze complex concepts, evaluate scientific information, and create evidence-based solutions to real-world problems. However, students' HOTS in biology learning remain a concern, particularly in courses involving abstract and interconnected concepts such as Human Physiology. This study aimed to examine the improvement of biology students' HOTS after the implementation of problem-based learning (PBL)-based student worksheets in a Human Physiology course. A pre-experimental design with a one-group pre-test–post-test model was employed, involving 34 biology students at a state university in Palembang, Indonesia. Data were collected using 15 essay questions developed based on the higher levels of Bloom's revised taxonomy, namely analyzing, evaluating, and creating. The instrument was validated and showed high reliability, with a Cronbach's Alpha value of 0.836. The data were analyzed using assumption tests and a paired-sample t-test at a significance level of 0.05. The results showed that the students' mean HOTS score increased from 47.40 in the pre-test to 74.22 in the post-test, with a statistically significant difference between the two scores ($p < .001$). These findings indicate that PBL-based student worksheets can support students in engaging with authentic physiological problems, conducting investigations, discussing evidence, and formulating solutions through structured learning stages. The study implies that PBL-based student worksheets can be used as an alternative instructional innovation to strengthen HOTS-oriented biology learning, particularly in courses that require conceptual integration, problem solving, and scientific reasoning.

Keywords: Biology Learning; Higher-Order Thinking Skills; Problem-Based Learning; Student Worksheets

INTRODUCTION

Higher-order thinking skills (HOTS) refer to students' capacity to achieve learning goals and respond to complex or unfamiliar situations by connecting prior knowledge with newly acquired knowledge (Lewis & Smith, 1993). In the revised version of Bloom's taxonomy, HOTS is represented by the cognitive processes of analyzing, evaluating, and creating (Anderson & Krathwohl, 2001). These processes require students not only to recall concepts but also to interpret evidence, examine relationships, judge the quality of arguments, and generate solutions to scientific problems (Lu, Pang, et al., 2021; Lu, Yang, et al., 2021).

HOTS is part of 21st-century skills and serves as a foundation for preparing students to face future academic, professional, and social demands (Utama et al., 2020). In science education, HOTS is central to meaningful learning because it enables students to use scientific concepts to explain phenomena, evaluate data, and solve real-life problems (Saido et al., 2015).

In biology education, these skills are particularly important because biological concepts are often connected to health, environmental pollution, food production, and other socioscientific issues that require evidence-based reasoning (Lameed et al., 2023; Retnawati et al., 2018).

Several studies have shown that students' HOTS in science and biology learning remains relatively low and needs further improvement (Amin et al., 2022; Arda, 2020; Sulistyorini et al., 2020). Undergraduate biology students may experience difficulty in solving C4, C5, and C6 questions because they are required to analyze data, justify arguments, and create solutions rather than merely recall concepts (Purwanti, 2020; Wijayanti et al., 2022; Yusuf & Widyaningsih, 2018). This problem is also relevant to Human Physiology learning, which is conceptually dense and requires students to connect structure, function, regulation, and disorders of body systems. Therefore, learning activities and teaching materials are needed to help students practice analysis, evaluation, and creation in a structured manner.

The development of HOTS can be integrated into biology learning through instructional designs that promote active inquiry, collaborative reasoning, and problem solving (Hujjatusnaini et al., 2022). HOTS development is also a major concern for educators and educational stakeholders because it contributes to the improvement of human resource quality (Abosalem, 2016; Ali & Zaini, 2023). In the learning process, carefully designed activities that create interaction between students and lecturers can stimulate students to reach higher levels of thinking (Insani et al., 2019). One practical strategy is to provide student worksheets containing tasks that guide students to understand concepts, investigate problems, and construct solutions (Nadifatinisa & Sari, 2021; Sari et al., 2023).

Student worksheets are teaching materials that can guide the implementation of learning activities in class (Puspasari & Puspasari, 2019). Worksheets can support students in discovering concepts and achieving higher-order thinking skills when they are designed around meaningful problems and structured inquiry activities (Khoiriah & Jalmo, 2020). Because worksheets can be developed according to the creativity and instructional needs of educators (Omanda et al., 2023), they may be integrated with active learning models such as Problem-Based Learning (PBL).

Problem-Based Learning (PBL) is an effective learner-centered learning model (Kasuga et al., 2022; Yew & Goh, 2016). PBL encourages independence, prepares students for lifelong learning, and promotes deep active learning (Wood, 2004). Through PBL, students are required to solve authentic problems, construct knowledge, develop inquiry skills, and strengthen higher-order thinking, independence, and self-confidence (Arends, 2012). PBL also enables more students to participate actively in class by identifying and solving unstructured daily-life problems (Choden & Kijkuakul, 2020; Gholami et al., 2016).

The use of PBL-based student worksheets in biology learning is expected to guide students to become more active while practicing HOTS in a systematic manner. In this study, the worksheet design followed the stages of PBL: orienting students to problems, organizing students to learn, guiding individual and group investigations, developing and presenting work, and analyzing and evaluating the problem-solving process (Arends, 2012). Similar studies have shown that PBL-based worksheets can support classroom activities and improve higher-order thinking skills (Puspasari & Puspasari, 2019; Wicaktini et al., 2020). However, the novelty of this study lies in the use of PBL-based worksheets in a Human Physiology course for biology education students, with HOTS assessment explicitly aligned with the analysis, evaluation, and creation dimensions of the revised Bloom's taxonomy.

PBL-based student worksheets were implemented in the Human Physiology course because this course is considered important yet challenging for undergraduate students (Rodrigues et al., 2024). Physiology is difficult to learn due to the nature of the discipline, the way it is taught, and the learning characteristics that students bring to the course (Michael,

2007). Students often face difficulties in understanding physiological mechanisms because the topics are detailed, integrated, and process-oriented (Colthorpe et al., 2018). Therefore, Human Physiology provides an appropriate context for applying PBL-based worksheets, because physiological disorders and body-system problems can be used as authentic cases that require analysis, evaluation, and solution design. Based on this background, this study aimed to examine whether PBL-based student worksheets were associated with an increase in biology students' HOTS. The research hypothesis was that students' HOTS scores would increase significantly after learning with PBL-based student worksheets.

METHODS

This study used a pre-experimental one-group pretest-posttest design. The intervention consisted of PBL-based student worksheets implemented during one semester in a Human Physiology course at one state university in Palembang City, Indonesia. The participants were 34 undergraduate biology education students enrolled in the course. They were selected as an intact class because the course had been scheduled before the study. The inclusion criteria were: (1) being officially enrolled in the Human Physiology course; (2) participating in the PBL-based worksheet activities; and (3) completing both the pre-test and post-test. Students with incomplete paired data were excluded from the analysis. Participation was voluntary, students were informed that the data would be reported anonymously, and permission was obtained from the relevant course or program authority. Since no comparison group was involved, this design was used to identify improvement after the intervention rather than to establish strong causal evidence.

Data on higher-order thinking skills were collected using a 15-item essay test referring to the top three cognitive levels of the revised Bloom's taxonomy: analysis, evaluation, and creation (Anderson & Krathwohl, 2001). The HOTS categories and subcategories are presented in Table 1. The instrument was developed to measure students' ability to analyze physiological problems, evaluate explanations or evidence, and create possible solutions related to Human Physiology topics. Responses were scored using an analytic rubric that considered conceptual accuracy, reasoning quality, evidence use, and the feasibility of the proposed solution.

Table 1. Categories of Higher-Order Thinking Skills

Category	Subcategory
Analysis	Differentiating
	Organizing
	Attributing
Evaluation	Checking
	Critiquing
Creation	Generating
	Planning
	Producing

The test blueprint is presented in Table 2 to clarify the alignment between Human Physiology topics, HOTS dimensions, item numbers, and scoring indicators. Before data collection, the validity and reliability of the HOTS questions were tested on 55 students who had taken the Human Physiology course. The results of the item validity test showed that the 15 essay questions were valid, with calculated r values greater than the r table value (r table = 0.266) and significance values below .05. The reliability test produced a Cronbach's Alpha value of 0.836, indicating very high internal consistency. Because the instrument used essay questions, future reporting should also include inter-rater reliability and the number of experts involved in content validation to strengthen evidence of scoring consistency.

Table 2. Blueprint of the HOTS Essay Test in Human Physiology

No.	Human Physiology topic	Item number(s)	HOTS dimension	Main cognitive demand	Scoring focus
1	Digestive system disorders	1-3	Analysis	Differentiate symptoms, organize evidence, and attribute causes to physiological mechanisms.	Concept accuracy and relevance of evidence
2	Respiratory system mechanisms	4-5	Analysis	Analyze relationships between structure, function, and respiratory regulation.	Logical explanation and causal reasoning
3	Circulatory system and homeostasis	6-7	Evaluation	Check the quality of explanations and evaluate alternative interpretations.	Use of criteria and justification
4	Excretory system and fluid balance	8-9	Evaluation	Critique proposed explanations or solutions for physiological problems.	Accuracy of evaluation and argument quality
5	Endocrine regulation	10-12	Creation	Generate and plan possible solutions for regulation-related cases.	Originality, feasibility, and scientific basis
6	Integrated body-system case	13-15	Creation	Produce integrated explanations and solutions involving more than one body system.	Integration of concepts and coherence of solution

The data were analyzed using a paired-sample t-test at a significance level of .05. Because the same students completed both the pre-test and post-test, the key assumption was the normality of the paired difference scores rather than the homogeneity of separate pre-test and post-test variances. Therefore, the assumption test focused on the distribution of the post-test minus pre-test scores. Homogeneity testing was not used because it is not required for paired data. In addition to statistical significance, the mean difference and normalized gain were reported to describe the magnitude of improvement

RESULT AND DISCUSSION

Assumption Testing

Before testing the research hypothesis, assumption testing was conducted to examine whether the HOTS pre-test and post-test data met the requirements for parametric analysis. The normality test was used to determine the distribution of the pre-test and post-test scores, while the homogeneity test was conducted as an additional check of score variance. The results of the assumption testing are presented in Table 3.

Table 3. Summary of Normality and Homogeneity Tests

No.	Data	Normality		Homogeneity
		N	Sig.	Levene's test
1.	Pre-test	34	0.108	0.167
2.	Post-test	34	0.124	

As shown in Table 3, the significance values of the normality test for both the pre-test and post-test scores were greater than 0.05. The pre-test score obtained a significance value of 0.108, while the post-test score obtained a significance value of 0.124. These results indicate that the HOTS scores were normally distributed. In addition, the Levene's test value was 0.167, which was also greater than 0.05, indicating that the data had homogeneous variance. Therefore, the data were considered suitable for further analysis using a paired-sample t-test.

Improvement of Students' HOTS after the Implementation of PBL-Based Student Worksheets

After the assumption testing was completed, a paired-sample t-test was conducted to examine whether there was a significant difference between students' HOTS scores before and after the implementation of PBL-based student worksheets in the Human Physiology course. The results of the paired-sample t-test are presented in Table 4.

Table 4. Summary of Paired t-Test Results

	Mean	**Sig. (2-tailed)**
Pre-test_HOTS	47.40	.000
Post-test_HOTS	74.22	
N	34	

Table 4 shows that the mean score of students' HOTS increased from 47.40 in the pre-test to 74.22 in the post-test. The mean difference between the pre-test and post-test scores was 26.82 points, indicating a substantial improvement after the implementation of PBL-based student worksheets. The significance value of the paired-sample t-test was .000, which is commonly reported as $p < .001$ in academic writing. This value is lower than the significance level of 0.05, indicating a statistically significant difference between students' HOTS scores before and after the intervention.

These findings suggest that the use of PBL-based student worksheets was associated with a significant improvement in biology students' higher-order thinking skills. In other words, the research hypothesis was supported: students demonstrated higher HOTS achievement after participating in learning activities structured through PBL-based student worksheets. However, because this study employed a one-group pre-test–post-test design, the findings should be interpreted as evidence of improvement after the intervention rather than as a fully controlled causal effect.

Discussion

The findings of this study indicate that students' higher-order thinking skills improved after the implementation of PBL-based student worksheets in the Human Physiology course. The increase in the mean score from 47.40 in the pre-test to 74.22 in the post-test demonstrates that structured learning activities based on real problems can support students in developing analytical, evaluative, and creative thinking. This result is consistent with Nanda et al. (2023), who reported that problem-based learning strengthened students' ability to analyze and evaluate biological concepts, particularly when learning activities required learners to solve contextual problems. The finding is also in line with Zulfah et al. (2022), who emphasized through meta-analytic evidence that PBL has a positive contribution to the development of higher-order thinking skills. Thus, the present study reinforces the argument that HOTS development requires learning models that actively involve students in problem identification, reasoning, evidence evaluation, and solution formulation.

The improvement in students' HOTS can also be understood through the role of student worksheets as instructional scaffolds. In this study, the worksheets were not merely used as supplementary teaching materials but were designed to guide students through the stages of problem-based learning. This finding supports the work of Kahar et al. (2021), who found that

HOTS-oriented worksheets can facilitate students' engagement with complex tasks and encourage higher-level cognitive processes. Similarly, Isnaeni et al. (2019) showed that problem-based worksheets on biological content could improve students' thinking skills by providing structured activities that required problem analysis and solution development. The present study extends these findings by applying PBL-based worksheets specifically in the Human Physiology course, a subject that contains abstract, systemic, and interrelated biological mechanisms.

The results of this study are also relevant to the findings of Kwangmuang et al. (2021), who argued that learning innovations designed to enhance HOTS should provide students with opportunities to construct knowledge, solve problems, and reflect on learning processes. The PBL-based student worksheets used in the present study provided these opportunities through activities such as orienting students to physiological problems, organizing learning tasks, conducting individual and group investigations, presenting findings, and evaluating the problem-solving process. These activities are closely related to the upper levels of Bloom's revised taxonomy, namely analyzing, evaluating, and creating. Therefore, the increase in HOTS scores can be interpreted as the result of the alignment between worksheet design, PBL syntax, and the targeted cognitive skills.

Furthermore, the findings are supported by Wijayanto et al. (2023), who showed that PBL supported by learning media can improve students' higher-order thinking and learning interest. In the present study, the worksheets functioned as a medium that organized learning activities and directed students to work independently and collaboratively. The integration of PBL syntax into the worksheets enabled students to engage with authentic problems and transform conceptual knowledge into problem-solving strategies. This finding is also consistent with Hidayati et al. (2023), who found that PBL-based learning supported by digital mind maps improved students' collaboration skills. Although the present study did not specifically measure collaboration, the learning process involved group investigations and presentations, suggesting that collaborative interaction may have contributed to the improvement of HOTS.

The present findings also correspond with Batlolona & Souisa (2020), who found that problem-based learning can help students construct mental models and improve conceptual understanding through investigation-based activities. In Human Physiology learning, students are required to understand the relationships among organs, systems, functions, and disorders. The use of real or contextual physiological problems encouraged students to connect theoretical concepts with biological phenomena. This process is important because HOTS cannot be developed only through memorization; it requires students to interpret information, evaluate evidence, and produce scientifically reasonable explanations. Therefore, the PBL-based worksheets helped transform physiology learning from content transmission into active inquiry and problem solving.

In addition, the role of interaction during learning is consistent with Lu, Pang, et al. (2021), who explained that collaborative inquiry-based learning can influence students' higher-order thinking through learning approaches and peer interaction. In this study, students were involved in discussions, group investigations, and presentation activities. These learning experiences required students to express ideas, compare arguments, evaluate alternative explanations, and revise their understanding. Such interaction may have strengthened students' analytical and evaluative abilities. This is also supported by Kurniawati & Hidayah (2021), who found that problem-based learning supported students' scientific literacy because students were trained to connect problems, concepts, evidence, and explanations. Although the present study focused on HOTS rather than scientific literacy, both constructs require reasoning, evidence evaluation, and problem-solving skills.

The findings further support Tama et al. (2020), who reported that problem-based learning activities involving planning, analyzing, and solving problems can improve higher-order thinking skills. In the present study, students were required to analyze physiological problems, identify relevant concepts, discuss possible causes, and evaluate solutions. These activities provided

repeated practice in applying HOTS indicators. The result is also consistent with Ulimaz et al. (2020), who emphasized that worksheets can help students develop concepts through individual and group activities. Therefore, the improvement in HOTS found in this study can be attributed not only to the PBL model itself but also to the way the worksheets structured students' learning experiences.

The novelty of this study lies in the integration of problem-based learning syntax into student worksheets specifically designed for the Human Physiology course to improve biology students' higher-order thinking skills. Previous studies have examined PBL, HOTS-oriented worksheets, or problem-based worksheets in different subjects and educational contexts. However, this study provides specific empirical evidence on how PBL-based student worksheets can be applied in a complex biology course that requires students to understand systemic physiological processes and relate them to authentic health-related problems. This study also highlights the potential of worksheets as structured pedagogical tools that connect biological content, problem-solving activities, and HOTS indicators within one learning design.

The theoretical implication of this study is that HOTS development in biology learning can be strengthened when learning activities are aligned with cognitive processes in Bloom's revised taxonomy and supported by inquiry-oriented problem-solving tasks. The findings suggest that students' ability to analyze, evaluate, and create can be developed through structured exposure to authentic problems, collaborative investigation, and reflective evaluation. From a pedagogical perspective, this study implies that lecturers should not use worksheets only as task sheets, but as learning scaffolds that guide students through meaningful problem-solving stages. In Human Physiology learning, PBL-based worksheets can help students move beyond memorizing organ functions toward interpreting physiological mechanisms, evaluating disorders, and proposing scientific explanations.

Practically, the results imply that PBL-based student worksheets can be used as an alternative instructional strategy for improving the quality of biology learning in higher education. Lecturers can adapt the worksheet design to other biology courses, especially those involving complex systems, causal relationships, and real-life biological problems. The worksheets may also support student-centered learning because they provide clear learning stages while allowing students to explore information, collaborate with peers, and construct solutions independently. Institutionally, the findings support the need to develop teaching materials that are aligned with 21st-century skills, particularly critical thinking, problem solving, collaboration, and higher-order thinking.

Nevertheless, this study has several limitations. First, the research employed a one-group pre-test post-test design without a control group. Therefore, although the findings show a significant increase in students' HOTS after the implementation of PBL-based student worksheets, the improvement cannot be attributed solely to the intervention with strong causal certainty. Second, the study involved only 34 students from one Human Physiology course at one university, which limits the generalizability of the findings to broader populations and different educational contexts. Third, the HOTS measurement focused on the cognitive domains of analyzing, evaluating, and creating, while other related skills such as critical thinking disposition, scientific reasoning, collaboration, and metacognitive regulation were not measured. Fourth, the study did not provide a detailed comparison of HOTS improvement across each indicator, so it remains unclear which aspect of HOTS improved the most after the intervention. Future studies should involve control groups, larger samples, different biology courses, and more comprehensive instruments to examine the effectiveness of PBL-based student worksheets more rigorously.

CONCLUSION

This study demonstrates that the implementation of problem-based learning (PBL)-based student worksheets was associated with a significant improvement in biology students' higher-order thinking skills (HOTS) in the Human Physiology course. The increase in the mean score

from 47.40 in the pre-test to 74.22 in the post-test, supported by the paired-sample t-test result ($p < .001$), indicates that structured worksheets integrating PBL stages can facilitate students' engagement in analyzing, evaluating, and creating solutions to physiological problems. These findings suggest that PBL-based student worksheets can serve as an alternative instructional innovation for promoting active, collaborative, and problem-oriented biology learning. The study contributes to the development of HOTS-oriented teaching materials by showing how worksheets can function not only as learning guides but also as scaffolds for systematic problem solving in a complex biology course. Nevertheless, the findings should be interpreted with caution because the study employed a one-group pre-test–post-test design without a control group and involved a limited sample from a single course context. Future research is recommended to employ a more rigorous experimental design, involve larger and more diverse samples, compare different biology topics, and examine HOTS improvement across specific indicators to provide stronger evidence regarding the effectiveness of PBL-based student worksheets in biology education.

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