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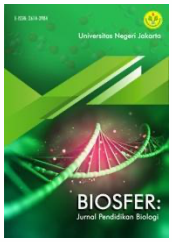

Effect of PBL model with student worksheets on biology learning: activities, thinking skills, and outcomes

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ABSTRACT

The low level of learning activities, analytical thinking skills, and student learning outcomes are indications of the need to improve the quality of learning through the implementation of innovative learning that makes students active subjects of learning in an effort to develop 21st century skills that are very important for students in facing the rapid development of science and technology today. This research aims to determine the effect of the PBL model assisted by student worksheets on learning activities, analytical thinking skills, and cognitive learning outcomes of class XI students at one of SMA Negeri in Medan City on the human immune system material. This material is very suitable for PBL because it contains complex biological processes and various disorders that involve the role of various components of the body. This research is quasi-experimental research with a non-equivalent pretest-posttest control group design. Samples were obtained through class randomization until 2 classes were obtained, where 1 class was an experimental class and 1 class was a control class. The data obtained were analyzed using an independent sample t-test which showed a significance value lower than 0.05. Students in the experimental group showed higher learning activity (78.53>64.47), better analytical thinking skills (77.88>70.32), and higher cognitive learning outcomes (81.91>70.44) compared to the control class. Thus, it can be concluded that the PBL model assisted by student worksheets has a significant effect on learning activities, analytical thinking skills, and cognitive learning outcomes of class XI students.

INTRODUCTION

Education is a systematic effort that is carried out with the aim of developing reasoning and problem-solving skills, as well as creating a productive, responsible society, and becoming lifelong learners both formally and informally (Ge et al., 2015). Along with the rapid advancement of technology in the 21st century, all areas of life have undergone significant changes. Education as one of the areas of life is also affected. Education in this century has undergone significant changes and progress in the implementation process. The 21st-century education is characterized by three aspects of skills, namely a way of thinking that includes creativity, innovation, critical thinking, and metacognition; ways of working that include communication and collaboration; and information and communication technology literacy as a work tool (Griffin & Care, 2015). These three aspects of skills are important to be developed in students as the next generation to face increasingly complex and multidisciplinary problems through the learning process (Ye & Xu, 2023). Likewise with Indonesia, the government has made efforts to improve the quality of education to develop 21st-century skills in students through replacing and adjusting the curriculum that contains the framework of the learning process that will be carried out by students (Hidayah et al., 2024).

Although various efforts have been made to improve the quality of education in Indonesia, some educational problems are still found. In the learning process, it was found that many students were not focused due to a lack of understanding of the learning implementation process in the classroom, the application of lecture methods that make learning teacher-centered, and the lack of use of teaching aids that support concept understanding (Amaliyah et al., 2024; Nurlaelah et al., 2021; Wahyuni et al., 2023). This causes low student curiosity in learning so that students become passive, reluctant to argue if the teacher is invited, and prefer to be silent even though there are things they do not understand (Dewi et al., 2023; Rahadiyani et al., 2023). Furthermore, learning that emphasizes memorizing concepts without connecting the material learned with contextual phenomena around students not only has a negative impact on concept understanding but also has an impact on students' thinking skills, one of which is analytical thinking (Dewi et al., 2023).

The analytical thinking skills refer to students' skills in finding the root of a problem through the investigation of the relationships between the key factors involved in a structured manner with deep understanding. With these skills, students will be trained to understand the underlying reasons for a problem and be able to come up with effective strategies to overcome them (Shiddiqi, 2024). Low analytical thinking of students is found in several developing countries. Indonesia as one of the developing countries has a low level of students' analytical thinking skills based on Indonesia's achievements in TIMSS in 2015 which shows that Indonesian students are not used to facing problems that require analytical thinking skills (Prawita et al., 2019). Judging from the three indicators of analytical thinking ability, namely differentiation, organization, and attribution, shows low results (Suyatman et al., 2021). The average analytical thinking skills of students at the secondary school level are relatively low because learning that uses contextual problems has not been implemented and science learning in schools only teaches theoretical concepts (Fadly, 2021; Ramadani et al., 2021). The low analytical thinking skills of students can cause students to have difficulty in determining the application of the concepts learned and other problems faced in everyday life (Ittaqi & Wardani, 2024).

This analytical thinking skill is very important to be given to students in order to be able to face problems that are increasingly complex. Moreover, with good analytical thinking skills, students can excel in their education. If problems related to these analytical thinking skills are not resolved immediately, there will be a significant decrease in student learning outcomes (Ittaqi & Wardani, 2024). Problems related to learning outcomes in learning are still found. One of them is in the senior high school digestive and respiratory system materials, where the average scores in each material were 56 and 53 which showed that the minimum completeness criteria had not been reached (Wahyuni et al., 2023). These low learning outcomes also occur due to monotonous learning and varied learning models, and the assumption of students that a material is difficult to learn. One of the materials that students find difficult is the human body's defense because it is complex and abstract (Cahyani et al., 2024; Pratiwi et al., 2023).

Based on the results of interviews and observations that have been conducted at SMA Negeri 1 Medan, it was revealed that a student-centered learning model that is PBL has been designed by teachers to be applied in the learning process in the classroom. However, this design has not been implemented optimally due to poor time management of teachers. Moreover, the absence of the use of

student worksheets as a student learning guide has an impact on low student learning activities because students lack understanding of how the learning process should be done, that characterized by students who do not answer when the teacher asks questions, do other subjects' assignments, and even play with gadgets. Low student learning activities lead to low understanding of students' concepts, so that their analytical thinking skills become low. This was marked during the question-and-answer session, where students only answered questions by guessing, so they were unable to provide more explanation. Learning outcome problems are also found in this school. The teacher only gives an assignment as an evaluation of learning in this chapter, and the teacher states that of the total, the students' score that fulfilment the minimum passing criteria, namely 77, did not reach 50%.

One of the efforts that can be made to overcome these problems is the application of a learning model that can increase student learning activities and improve students' analytical thinking skills in the teaching and learning process. One of the learning models that can be applied is problem-based learning (PBL). PBL is a learning model that uses contextual problems so that it can train students to think critically, creatively, and collaborate in finding the best solutions to solve these problems (Vivilia et al., 2024). In this model, problems are used as a stimulus that is expected to encourage students to be able to formulate a hypothesis using their knowledge, seek information through discussion to get the right solution, so that the teaching and learning process carried out with this model will be student-centered, not teacher-centered (Simeru et al., 2023).

In its implementation, the application of this model will be assisted by the use of student worksheets as a guide for teaching and learning activities in the classroom for students. Student worksheets are one of the teaching materials that can make student-centered learning because it contain summaries and accompanied by instructions so that teachers are no longer the only source of learning for students (Rahmi et al., 2023). Several previous studies have proven that PBL models and student worksheets are effective in improving science literacy scores and learning outcomes in respiratory and excretory system materials analyzed with N-Gain, as well as increasing student cooperation in biology learning through classroom action research (Cahya et al., 2023; Sari et al., 2024). In addition, there are also other studies that apply the PjBL model assisted by student worksheets, which show that the application of this treatment improves student learning activities and learning outcomes (Tarigan & Latief, 2022). Research with R&D methods has also been conducted to develop student worksheets and has been shown to be effective in improving learning interest, science process skills, and learning outcomes in biodiversity and viruses materials (Gultom et al., 2024).

Based on several of these studies, it is known that there has not been research that simultaneously investigates the three aspects of learning in the form of learning activities, analytical thinking skills, and students' cognitive learning outcomes using a complete quasi-experimental research design. Not only that, but analytical thinking skills also that are part of high-level thinking skills are still rarely studied explicitly in the context of the application of the PBL model assisted by student worksheets. With this gap, this research is important to expand the findings so as to add to the basis for designing and implementing innovative learning that is important in developing 21st-century skills in students. Thus, this study was conducted to determine the effect of the problem-based learning model assisted by student worksheets on learning activities, analytical thinking skills, and students' cognitive learning outcomes, especially in human immune system materials.

METHODS

Research Design

The research design used in this research is a quasi-experiment non-equivalent pretest-posttest control group design (Sugiyono, 2017). The description of this research design can be seen in Table 1.

Table 1.
Research Design

Class	Pretest	Treatment	Post-test
Experiment	O_1	X	O_3
Control	O_2	O	O_4

Infromation:
O_1 : Experimental class that given a pretest

O_2 : Control class that given a pretest
X : The experimental class that given a treatment in the form of applying the PBL model assisted by student worksheets
O : The control class is not given treatment and taught with a direct learning model in accordance with usual learning used by the teacher
O_3 : Experimental class that given a posttest
O_4 : Control class that given a posttest

Population and Samples

The population in this research is all class XI that participate in biology learning, which consists of 9 classes, namely class XI-1 to XI-9, with a total of 324 students. The sample in this research consists of 2 classes, namely 1 experimental class and 1 control class. The sampling technique used is cluster random sampling**,** where the selection of classes is carried out randomly by the researcher assuming that all members in the class are homogeneous and have the same characteristics. Through this technique, class XI-2 was selected as an experimental class taught with a problem-based learning model assisted by student worksheets as the treatment provided and class XI-1 as a control class taught with a direct learning model as the learning that is usually carried out by teachers. The students in each sample class consisted of 34 students, so that the total number of students sampled in this research was 68 peoples.

Instrument

According to the dependent variables in this research, the instruments used are divided into 2 types, namely non-test and test. The non-test instrument used was an observation sheet used by 2 observers to obtain data on student learning activities, such as visual observed from the student's activities in paying attention to the teacher's explanation; oral observed from students' activities in asking questions and arguing during the learning process; listening observed from the student's activities in listening to the explanation of the teacher and friends during the results presentation; writing observed from students' activities in writing or recording things related to the learning process; and emotional activities observed from students' interest in the learning process that occurs. In addition, this research also uses 2 different test instruments, namely an essay test to obtain data on students' analytical thinking skills and a multiple-choice test to obtain data on students' cognitive learning outcomes. The essay test was chosen to measure students' analytical thinking skills because it requires students to be able to compose, organize, and formulate answers using their own words so that students' thinking skills and flow of thought can also be measured (Rahman & Nasryah, 2019), while multiple-choice tests were chosen to measure students' cognitive learning outcomes because they allow for more complex measurements that cover diverse cognitive levels (Ropii & Fahrurrozi, 2017). These two instruments are compiled based on Bloom's cognitive theory, where the essay test focuses on the C4 level, which consists of 3 indicators, namely differentiating, organizing, and attributing (Blegur et al., 2023), while the multiple-choice test focuses on the high cognitive level, namely C4-C6 (Asrul et al., 2015). All instruments used in this research have been validated by experts, and the test instrument has been tested on students, and then the test results data are used to analyze the quality of the questions presented in the instrument. The grid of analytical thinking skills essay tests can be seen in Table 2, and the multiple-choice test of cognitive learning outcomes in Table 3.

Table 2.
Grid of Analytical Thinking Skills Essay Test

No	Indicators	Analytical Thinking Skills Indicator			Number of Questions
		Differentiating	Organizing	Attributing	
1	Explain the structure and function of the body's organs as an external defense system			1	1
2	Analyze the internal body's defense system	2			1
3	Analyze the effect of antigens on the human body's defense response		3	4	2
4	Analyze the formation process of human body's defense	5			1

5	Explain disorders and ways of preventing diseases related to the human body's defense system		6		1
	Number of Sub-Questions	**2**	**2**	**2**	**6**

Table 3.
Grid of Cognitive Learning Outcomes Multiple-Choice Test

No	Indicators	Cognitive Domain			Number of Questions
		C4	C5	C6	
1	Analyze the mechanism of the non-specific body's defense system appropriately according to the given case	5, 7			2
2	Analyze the mechanisms of the body's specific defense system precisely according to the list of processes given	8, 9			2
3	Analyze the role of vaccines in controlling the spread of diseases caused by viruses based on the data provided	11			1
4	Analyze the level of accuracy of the techniques used in detecting the Covid-19 virus based on the graph provided	15			1
5	Evaluate the importance of the body's defense system components against disease based on the given case		1, 2		2
6	Evaluate several ways to treat the disorder and increase the body's immunity based on the case and information provided		17, 16, 18		3
7	Creating appropriate solutions to cases of distruption of the role of components and the response of the body's defense system			3, 19	2
8	Creating experimental ideas to describe the role of components and responses of the body's defense system based on the discourse given			4, 6	2
9	Creating innovative ideas to improve the effectiveness of therapy in overcoming diseases due to pathogenic infections based on the discourse provided			13, 10, 14	3
10	Creating the right solution to overcome abnormalities in the body's defense system based on the principle of body immunity based on the given case			12, 20	2
	Number of Questions	**6**	**5**	**9**	**20**

Procedure

The procedures carried out in this research are divided into 3 stages, namely the preparation stage, the implementation stage, and the final stage. The preparation stage is carried out for 2 months which begins with the identification of problems through a number of literatures which is then adjusted to the results of problem identification at the target school based on the results of interviews, observations, and documentation studies to produce a research proposal equipped with all valid research instruments. The three instruments used were observation sheets for learning activities, an essay test for analytical thinking skills, and multiple-choice tests for students' cognitive learning outcomes, each of which was validated by an expert. For the 2 test instruments that were declared valid by experts, it was followed by prediction validation by conducting test questions for each of the 36 students in grade XII of high school to obtain data to test the validity, difficulty, differentiation, and reliability of the test. After all instruments are declared valid, the process continues by obtaining research permits.

The obtaining of research permits is the beginning of the implementation stage. This stage begins by providing a pre-test in the form of 6 essay questions for analytical thinking skills and 20 multiple-choice questions for cognitive learning outcomes to students in both classes to obtain data on students' initial abilities. This stage is then continued with the application of a problem-based learning model assisted by student worksheets in experimental classes, where the learning process is focused on solving problems given in student worksheets collaboratively in groups that start with problem-orienting, forming 5 heterogeneous groups based on gender, guiding individual/group investigations in

the form of discussions, developing and presenting results in the form of results presentation, and ended by conducting analysis and evaluation of the problem-solving process carried out in the form of reflection activities. The treatment in this experimental class was applied during 3 meetings facilitated by the researcher as a substitute for the teacher.

With the same number of meetings, the control class applied a direct learning model, where the learning process is still dominated by the role of the researcher as a substitute for the teacher in delivering the learning material, but students have been facilitated to discuss in understanding the concept of using package books. Learning begins with providing explanations related to learning objectives and forming 5 heterogeneous groups based on gender, explaining the material, providing exercises in guidance, giving feedback and examining understanding, and also providing advanced training and application to students. During the learning process that took place in the 2 classes, observation sheets were also used by 2 observers to obtain data related to student learning activities. After the material is completed, the treatment is also completed.

In the final stage, students were tested again using the same test instrument, namely 6 analytical thinking skills essay questions to obtain data on students' analytical thinking skills after treatment and 20 multiple-choice questions to obtain data on students' cognitive learning outcomes after treatment. By comparing the results after treatment on the two variables, it is known that the effectiveness of the application of the treatment designed in this research to all dependent variables that have been determined.

Data Analysis Techniques

All data obtained in this research were analyzed using the independent sample t-tests ($p < 0.05$). Before the independent sample t-tests are carried out, the data will go through a prerequisite test in the form of a data normality test using the Shapiro-Wilk's test and data homogeneity using the Levene's test.

RESULTS AND DISCUSSION

1. Students' Learning Activities through the Application of PBL Model Assisted by Student Worksheets

The data on student learning activities obtained had a normal distribution ($p = 0.800$; $p = 0.241$; $p = 0.384$; $p = 0.328$) and homogeneous variance ($p = 0.343$; $p = 0.505$) based on the acquisition of a Sig. > score of 0.05 in each class and treatment. Thus, this data can be continued with an independent sample t-test as a hypothesis test with a visualization of the results that can be seen in Figure 1.

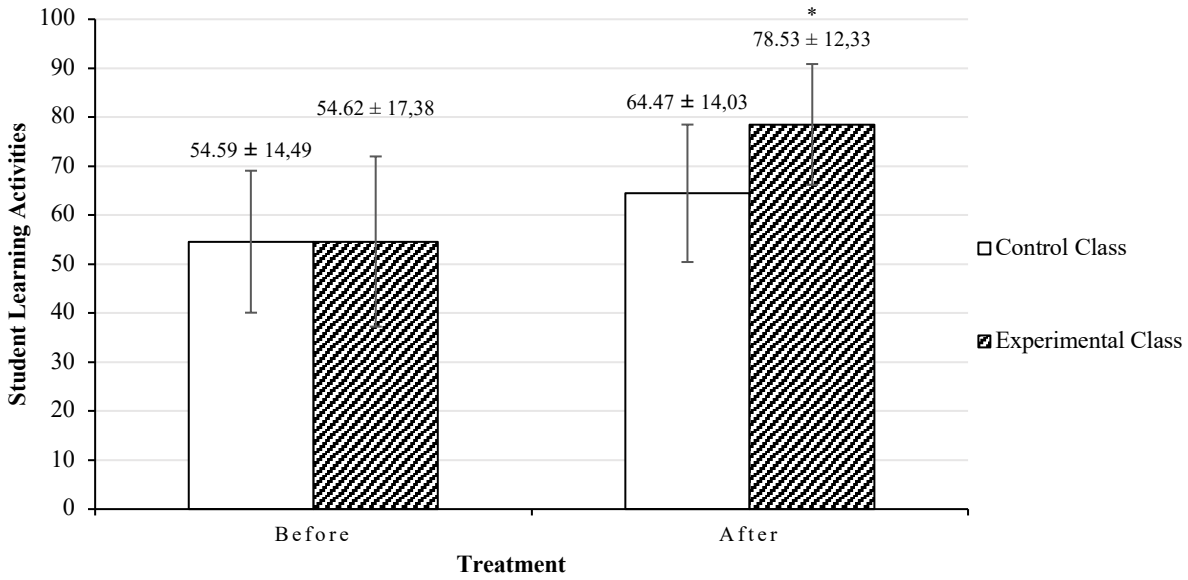

Figure 1. The Effect of Problem-Based Learning Model Assisted by Student Worksheets on Student Learning Activities. The learning activities of students after treatment in the experimental class (78.53 ± 12.33) were higher compared to the control class (64.47 ± 14.03). Asterisk indicates a very significant difference in the experimental class based on the results of the t-test ($p = 0.000$; Sig. (2-tailed) < 0.05).

Referring to Figure 1, after receiving the treatment, the learning activities of students in both

classes showed a difference. This difference can be seen in the higher average final score of the experimental class than the control class (independent sample t-test, p = 0.000, which is smaller than the significance level of 0.05). These results prove that Ha is accepted, which means that there is a significant effect on the application of the problem-based learning model assisted by student worksheets on student learning activities. Students in classes taught with the PBL model assisted by student worksheets showed higher activities (79%) that included in the active category, while student learning activities in the control class is lower (64%) and included in the moderately active category.

The increase in student learning activities in the experimental class after treatment occurred because the learning that took place was no longer teacher-centered, but student-centered (Ulimaz et al., 2023). In this learning, students carry out the learning process in a collaborative, structured and systematic manner so as to create a diversity of learning activities which is shown by the improvement of communication skills as part of oral activities; collaboration, thinking, and problem-solving skills as part of visual, oral, listening, writing, and emotional activities (Sakir & Kim, 2020). The main feature that supports this learning model, which is able to facilitate student-centered learning, is the use of contextual problems as a stimulus that directs collaborative learning for students in the form of investigation (Uluçinar, 2023). With collaboration, the process of active discussion between students and teachers, and peers will have a positive effect on improving their learning activities (Handayani et al., 2022).

Judging from each syntax of this learning model, learning that begins by orienting contextual problems can trigger students' curiosity so that students are excited to be actively involved in solving the given problem (Barus & Purba, 2024), then continue by organizing students to learn which is the basis for collaboration in learning groups (Hendarwati et al., 2021). The learning groups that have been formed allow students to divide tasks in investigations both individually and in groups through literature search and discussion, thus creating increasingly interactive learning conditions (Irwandi et al., 2024). After the investigation is completed, it will be continued with the stage of developing and presenting the findings in front of the class, which can train students' confidence and communication skills (Arum & Hikmat, 2024). This learning will end with the analysis and evaluation stage of the problem-solving process, where the teacher will reflect, strengthen, and evaluate the problem-solving process that students have done so that students can improve the quality of their learning in the next learning (Simeru et al., 2023).

The creation of student-centered learning can be supported by the use of teaching materials that act as learning guidelines, one of which is student worksheets (Biantoro & Pertiwi, 2024). The use of student worksheets in the learning process can increase student learning independence (Mykytyn et al., 2024). Student worksheets that are arranged in accordance with the PBL syntax and contain contextual problems will guide students in the learning process, including encouraging them to conduct experiments, research, and investigations that improve student learning activities so that students' knowledge does not only come from the delivery of material by teachers (Astuti & Octavia, 2023). The assignments presented in the problem-based student worksheets facilitate students' active participation through the process of collaborative information exchange and improve communication skills as a part of students' oral activities through discussion activities (Susetyarini et al., 2022).

This finding is supported by Zuhrotunnisa et al (2020), who stated that a problem-based learning model assisted by student worksheets can facilitate students' learning independence, which can increase their learning motivation so as to encourage students to be actively involved in the learning process. Strengthened by the findings of Milliniawati & Isnaeni (2023), the implementation of PBL assisted by student worksheets makes it easier for students to carry out various learning activities with the role of the teacher as a facilitator. Student worksheets that contain PBL syntax as a learning stage that starts with problem orientation until conclusions are obtained will train and increase students' active participation in learning. Diverse learning activities will help students in the problem-solving process and train students to think in finding the best solution to the given problem so that students' understanding of a material is deeper and the learning carried out is more meaningful.

In line with Vygotsky's theory of constructivism, the knowledge gained by students is actively and independently constructed during the learning process. In this case, students are required to be active in thinking, drafting concepts, and giving meaning to what they have learned (Sartika et al., 2022). This approach also emphasizes that student activity in learning, supported by the provision of materials, media, environment, and other facilities, allows the creation of student interaction with their learning

environment to play an important role in the process of building knowledge in students (Nurhayani & Salistina, 2022). Thus, it can be understood that the treatment of the problem-based learning model is able to create student-centered learning and is supported by the use of teaching materials in the form of student worksheets, allowing student interaction with their learning environment so that this treatment increases student learning activities in building their knowledge.

In the implementation of this research, there are several limitations, including the short duration of the research so that the long-term effect cannot be measured, control of factors that affect student learning activities, such as family support and motivation, has not been carried out, and assessments that only use observation sheets cause bias due to observer subjectivity. However, the results of the study show that there is a significant increase in student learning activities through the application of this treatment. Based on the description above, it can be understood that the application of the PBL model assisted by student worksheets can be used as one of the learning strategies that can be considered in an effort to improve student learning activities. Not only that, to obtain more consistent and comprehensive treatment effectiveness investigation results, it is necessary to increase the duration of the research, control of factors that affect student learning activities, and the addition of instruments in the form of interview sheets or questionnaires to avoid observer subjectivity in the next research.

2. Students' Analytical Thinking Skills through the Application of PBL Model Assisted by Student Worksheets

Based on the results of the prerequisite test, the data on students' analytical thinking skills were distributed normally (p = 0.073; p = 0.317; p = 0.070; p = 0.252) and homogeneous (p = 0.823; p = 0.888), which was shown with a Sig. value of > 0.05 in each class and treatment. With the fulfillment of normal and homogeneous data assumptions, it is continued with an independent sample t-test as a hypothesis test with a visualization of the results that can be seen in Figure 2.

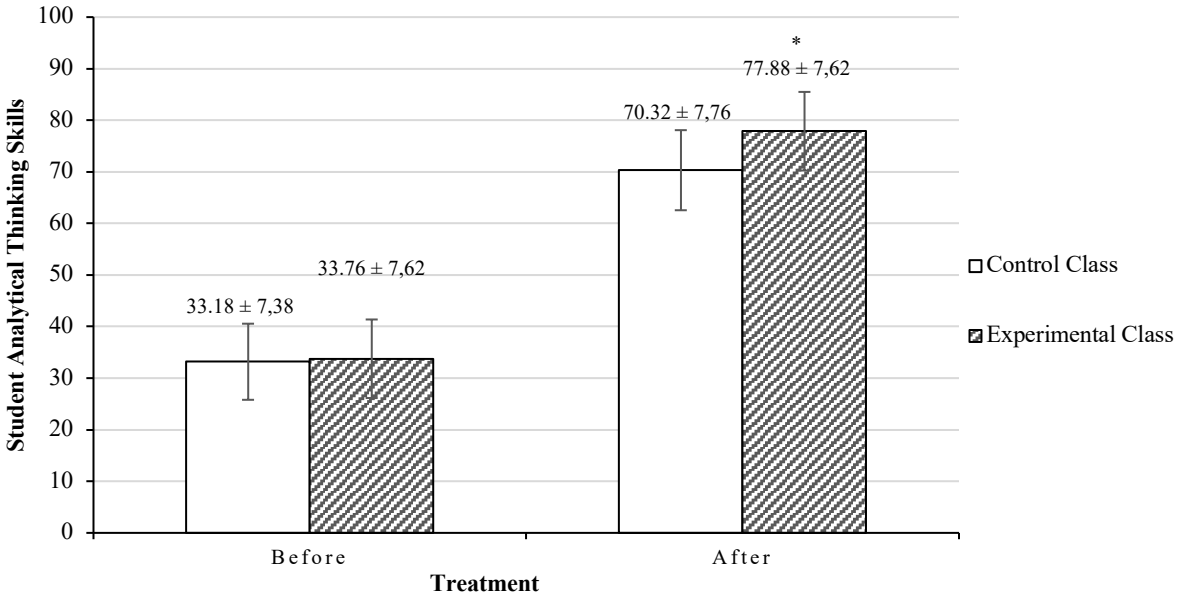

Figure 2. The Effect of Problem Based Learning Model Assisted by Student Worksheets on Student Analytical Thinking Skills. The students' analytical thinking skills after treatment in the experimental class (77.88 ± 7.62) were higher compared to the control class (70.32 ± 7.76). Asterisk indicates a very significant difference in the experimental class based on the results of the t-test (p = 0.000; Sig. (2-tailed) < 0.05).

According to Figure 2, students' analytical thinking skills after being treated showed positive results. Students in the experimental class had better analytical thinking skills when compared to the control class. This result was reinforced by the acquisition of a Sig. (2-tailed) value on an independent sample t-test (p = 0.000), which was smaller than the significance level of 0.05. Thus, it is proven that the Ha is accepted, which means that there is a significant effect on the application of the problem-based learning model assisted by student worksheets on students' analytical thinking skills. Students in the experimental class had better analytical thinking skills (77.88 ± 7.62) compared to students in the

control class (70,32 ± 7,76).

The analytical thinking skills of students in the experimental class after treatment are better because the learning that students receive not only involves listening to the teacher and memorizing theories and concepts, but also encourages students to think rationally through the given problems. The implementation of the PBL model syntax in this study is in line with the characteristics of the constructivism theory that proposed by Driver and Oldhan (1994), which consists of: 1) the existence of orientation carried out to increase the motivation of students in studying a topic through the observation process, 2) the existence of elicitation carried out to facilitate students to explore their ideas through the discussion process, 3) the restructuring of ideas carried out to compare students' ideas with other opinions to assess the quality of the ideas they have, 4) the application of ideas where students are allowed to apply the knowledge that has been obtained in various situations, 5) the existence of a review that provides opportunities for students to assess the application of the ideas that have been carried out (Sartika et al., 2022).

In general, the improvement of students' analytical thinking skills through the application of the PBL model occurs because this learning model can train students to understand new knowledge in a systematic, comprehensive, and in-depth manner so that they can understand the application of these concepts in the real world through the active participation of students in independent and group investigations under the guidance of teachers as facilitators (Lane, 2020; Suyatman et al., 2021). The use of contextual problems as the main feature in this learning model is an important thing that must be conveyed to students because it can stimulate their desire to solve problems systematically through hypothesis formulation, search for relevant information, and group discussions in analyzing the best solution to the given problem (Simeru et al., 2023). In line with the theory of constructivism, which states that students' understanding of something must be built independently by students through a process of investigation and discovery so that the new knowledge they gain is comprehensive and in-depth (John & Thomas, 2018). The acquisition of comprehensive and in-depth new knowledge obtained through meaningful learning is also supported by Ausubel's cognitive theory, which states that meaningful learning occurs when the learning is carried out, facilitating the incorporation of new information with the students' previous understanding (Sartika et al., 2022).

The improvement of students' analytical thinking skills can also be supported by the use of teaching materials that are systematically and completely arranged so that they are able to facilitate active participation and independence of students in learning. One of the teaching materials that fits this characteristic is student worksheets. The use of student worksheets as a learning guideline can realize students' active participation in learning (Mumtaza & Zulfiani, 2023). Students' active participation in learning affects their learning independence. Student worksheets can facilitate student learning independence because the components presented in it contain materials, summaries, practice questions, and instructions for the implementation of assignments by students (Hasanah et al., 2018). Learning independence also plays an important role in affecting students' analytical thinking skills because students with a good level of independence will always have the initiative to search and find information that supports their learning process through the search for accurate and relevant sources so that students' knowledge does not depend only on the information provided by the teacher (Fitriani & Fadly, 2022).

Supporting the findings in this research, Sujana (2023) revealed that the problem-based learning model assisted by student worksheets can improve analytical thinking skills as part of higher-level thinking skills because it requires students to not only remember but also be able to process the information received to generate new ideas or solutions with the help of student worksheets as a learning guide. Strengthened by the findings of Biantoro & Pertiwi (2024) the PBL model can be integrated with worksheets that direct students in the learning process as one of the efforts to improve science literacy skills and collaboration which is an important part of efforts to train students' analytical thinking skills by using contextual problems as student tasks. These contextual problems will be a stimulus for students in the learning process that requires complex and deep-thinking skills in the solving process. Thus, it can be understood that the implementation of PBL that contains contextual problems with the help of student worksheets is able to create learning that supports the development of students' analytical thinking skills because the problem oriented is used as an assignment that must be solved by students by being guided by the work steps adopted from the PBL syntax in it.

In the implementation of this research, there are several limitations, including that students are not used to learning that requires analysis of problems, short research duration, not yet combining learning models that can support each other, and the worksheets used are still in the form of hard copies. To maximize the effectiveness of the treatment in this research, the researcher, as a facilitator, provides extra motivation and guidance to students during the learning process and chooses problems that are in accordance with the material studied and are contextual. Thus, the results of the research show that there is a significant improvement in students' analytical thinking skills through the application of this treatment. Based on the description above, it can be understood that the application of the PBL model based on student worksheets can be used as one of the learning strategies that need to be considered in an effort to improve students' analytical thinking skills. The results of this study strengthen the constructivism model where the PBL model assisted by student worksheets increases student activities in problem solving so as to train students' analytical thinking skills which are important in the knowledge acquisition process. Not only that, the results of this research can also be used as a basis for developing teaching materials and other learning components in an effort to create student-centered learning. Thus, to expand on the findings in line, further research is suggested to increase the duration of the study, combine PBL models or other learning models with mutually supportive learning models, and use digital student worksheets that facilitate student access.

3. Students' Cognitive Learning Outcomes through the Application of PBL Model Assisted by Student Worksheets

The data on students' cognitive learning outcomes were shown to have a normal distribution (p = 0.127; p = 0.114; p = 0.170; p = 0.314) and homogeneous variance (p = 0.913; p = 0.551) based on the acquisition of a Sig. > score of 0.05 in each class and the treatment. Based on these results, the data was analyzed using an independent sample t-test to test the research hypothesis, with a visualization of the results that can be seen in Figure 3.

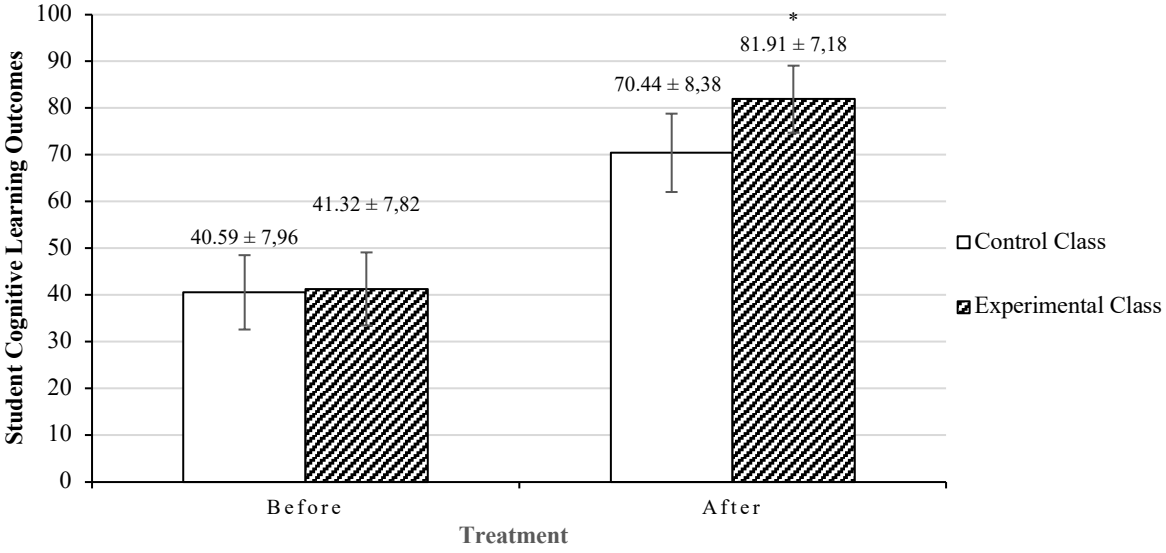

Figure 3. The Effect of Problem-Based Learning Model Assisted by Student Worksheets on Student Cognitive Learning Outcomes. The cognitive learning outcomes of students after treatment in the experimental class (81.91 ± 7.18) were higher compared to the control class (70.44 ± 8.38). Asterisk indicates a very significant difference in the experimental class based on the results of the t-test (p = 0.000; Sig. (2-tailed) < 0.05).

The data in Figure 3 shows that the learning outcomes of students in the experimental class who learn using the PBL model assisted by student worksheets are higher (81.91 ± 7.18) than in the control class that teaches using the direct learning model (70.44 ± 8,38). This result was reinforced by the acquisition of a Sig. (2-tailed) value on an independent sample t-test (p = 0.000), which was smaller than the significance level of 0.05. Thus, Ha is accepted, which means that the application of the PBL model assisted by student worksheets has been proven to have a significant effect on student learning outcomes.

The improvement in student learning outcomes in the experimental class after treatment occurred because the PBL model applied encouraged students to be actively involved in the problem-solving process, given so that students were able to understand the concept and its application in daily life. This learning process makes learning more in-depth and meaningful for students so that in the end, there is an improvement in aspects of their learning outcomes (Pratiwi et al., 2023; Putri et al., 2024). The PBL model also facilitates collaboration-based learning, so that in the problem-solving process carried out by students can collaborate with friends in their group through the division of tasks in the investigation process, which allows for a lot of information acquisition. The amount of information obtained makes students' knowledge of a concept related to the problem broader. This broad knowledge is what improves student learning outcomes because students have a good understanding of concepts (Sidiki et al., 2024). In addition, students who are trained to solve problems in a structured manner and are actively involved will be able to evaluate their learning process so that it has a positive impact on their cognitive learning outcomes (Suryanti & Festiyed festiyed, 2023).

Students who are trained to solve problems through the search for solutions to the problems they face will develop their cognitive abilities (Cahya et al., 2023). The development of cognitive abilities with the application of the PBL model occurs continuously according to each syntax. In the first syntax, PBL uses problems as a stimulus to encourage students to think, then continues with collaboration in groups as an effort to investigate through various sources, followed by developing and presenting results based on the results of the investigation, and ending with analyzing and evaluating the problem-solving process that has been carried out (Salamun et al., 2023). This is in line with the 3 stages of learning in the cognitive learning theory proposed by Piaget, namely starting with the stage of integrating new knowledge with previously possessed knowledge known as the assimilation stage, then applying the knowledge to different conditions known as accommodation, and ending with the process of adjustment between the assimilation and accommodation stages which is carried out continuously to ensure addition and development of knowledge possessed by students (Nurhayani & Salistina, 2022).

In an effort to improve students' cognitive abilities that have an impact on their cognitive learning outcomes, the use of teaching materials in the form of student worksheets can be used. Student worksheets designed by teachers can improve student learning outcomes because it can facilitate discussion activities that allow for the exchange of information between students in groups so as to train students' skills in expressing opinions based on their understanding (Hatiti et al., 2021). Moreover, the use of student worksheets that contain a summary of the material, practical questions, and guidelines can stimulate thinking skills and facilitate the acquisition of broader knowledge for students so that there is an increase in their learning outcomes (Panjaitan & Sidabutar, 2023). The successive stages and instructions in the student's worksheet will focus the learning process in accordance with the learning topic discussed, so that the search for information by students does not go out of the learning content being studied (Arum & Hikmat, 2024).

The application of a combination of problem-based learning models and student worksheets has a very significant effect on students' cognitive learning outcomes on human immune system materials. A significant effect occurs because the application of the PBL model assisted by teaching materials in the form of student worksheets can facilitate students' active participation during the learning process through a series of structured problem-solving activities. This treatment can improve students' concept comprehension, higher-order thinking skills, and problem-solving abilities through the process of analysis, synthesis, and evaluation (Mandey et al., 2024). In line with Vygotsky's constructivist theory, which states that students who learn by building their own knowledge make learning more meaningful so that understanding lasts longer than learning that only receives information or knowledge without a thought process characterized by the student's ability to apply their understanding to different conditions (Wahab & Rosnawati, 2021).

Strengthened by the findings of Astuti et al., (2023), PBL-based worksheets can trigger students' curiosity about the given problems, so as to encourage students to actively participate in learning. Learning that increases students' direct involvement in acquiring knowledge will make students' understanding of a concept deeper. A deep understanding of a concept has a positive effect on students' cognitive learning outcomes. In line with the findings of (Milliniawati & Isnaeni, 2023), the PBL model assisted by student worksheets can increase students' motivation and interest in learning so that the process of students' understanding of a material becomes easier. This easier comprehension process can ultimately improve students' cognitive learning outcomes. This increase in cognitive understanding

and learning outcomes is facilitated by the presence of contextual problems presented in student worksheets so that students not only memorize the concepts contained in the book, but more than that, students will understand the basic concepts taught (Nurjannah et al., 2022). Thus, the application of this combination of treatments can improve students' cognitive learning outcomes through increasing students' curiosity, activities, learning, and cognitive abilities.

In the implementation of this research, there are several limitations, including requiring longer preparation time, students are not yet familiar with problem-based learning, differences in students' learning interests, and the unavailability of learning facilities in the form of projectors in good condition, resulting in less-than-optimal presentation of problem-solving results by students. However, the results of the research show that there is a significant increase in student learning outcomes through the application of this treatment. Based on the description above, it can be understood that the application of the PBL model based on student worksheets can be used as one of the learning strategies to improve students' cognitive learning outcomes. Thus, to increase the effectiveness of this treatment, further research is recommended to extend the duration of the study to provide students with the opportunity to adapt optimally to the learning given, consider learning variations by applying a differentiated learning approach, and increase the variety of learning media by making optimal use of students' personal devices.

CONCLUSION

The application of the PBL model assisted by student worksheets has been shown to be more effective because it is able to improve learning activities, analytical thinking skills, and cognitive learning outcomes of students of grade XI high school students on the material of the human immune system. Teachers as learning designers in schools are advised to consider the application of this treatment as one of the efforts to improve student-centered learning so as to improve the quality of learning for students. In order to obtain relevant and more optimal findings, some limitations in this research such as learning strategies, duration, and instruments need to be improved in future research.

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