The influence of problem based learning model and critical thinking ability on higher order thinking skills (HOTs) of physics prospective teachers students

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Abstract. This study aims to determine the effect of applying problem-based learning models, critical thinking skills, and their interactions on students' higher-order thinking skills in optical materials. The research method used is a quasi-experimental method with a two-way ANOVA design. This research was conducted at IKIP PGRI Pontianak in the second-semester students of the physics education study program as many as 34 students. Data on students' higher-order thinking skills were obtained using multiple-choice tests with reasons, while data on students' critical thinking skills were measured using multiple-choice tests. Based on the results of data analysis, it can be concluded that: The ability of prospective physics teacher students to complete the HOTS-based physics test is better after the problem-based learning model is applied. Future physics teacher students with high critical thinking skills have better performance in meeting HOTS-based physics tests. There is an interaction between applyingicip2021est the problem-based learning model and the essential skills of thinking of prospective physics teacher students in completing the HOTS-based physics test. Implementation of the problem-based learning model is vital for other physics materials. In addition to improving the understanding of physics concepts, it also enhances higher-order thinking skills for prospective physics teacher students.

1. Introduction
The education sector has a vital role in the development of a nation. An advanced country is supported by education that can develop the potential possessed by students so that students can independently solve the problems they face. Furthermore, the importance of the concept of education that is learned will be felt if one enters social life, especially when one enters the world of work because the ability to apply concepts that have been discovered in school will be used in dealing with the problems of everyday life both useful now and in the future [1]. Therefore, education must be managed professionally by individuals who have superior competence in the field of education.

However, based on the results of observations and interviews conducted with several student teacher candidates, information was obtained that students were less independent and had difficulty solving problems when faced with a problem. One of the causes of these problems is the application of learning that does not focus on students. The paradigm that the lecturer is the only primary source of knowledge who is an expert in his field is still firmly held by students so that students do not get a good process and understanding of knowledge. Knowledge is only obtained from lecture notes. The lack of student involvement in the learning process causes students to become independent. As a result, the thinking process is not carried out properly so that a meaningful learning process is not achieved.
Prospective physics teacher students must master physics content knowledge. Physics is the most fundamental physical science and deals with the basic principles of the Universe. Physical science is the foundation on which other sciences such as astronomy, biology, chemistry, and geology form the basis for most engineering applications [2]. Physics is also a science-based on experimental observations and measurements of physical quantities [3]. Studying physics will be challenging, sometimes frustrating, and often very rewarding [4]. As a fundamental science, physics is helpful for understanding applied science and as a basis for technological development. In studying physics, students are given knowledge and experience of physics concepts. In addition, students are trained to be skilled in scientific work to solve various problems in everyday life [5]. In other words, the purpose of studying physics is to provide knowledge and understanding of physics concepts, apply them in solving various problems of daily life, and communicate them well in society and the world of work. Then, the implementation of learning physics is also expected to increase the development of science and technology, environmental conservation, and Indonesia's natural wealth.

Introductory Physics Lecture is one of the subjects that prospective physics teacher students must take. This is intended to master the basic concepts of physics to equip students to learn more complex physics material or concepts. However, the first-year students still have difficulty understanding these basic concepts. Physics concepts that are considered difficult for students include visual concepts. Based on research conducted by Ref [6,7], shows that students experience misconceptions about visual concepts. The misconceptions found include the concepts of (1) image formation on concave mirrors, convex mirrors, plane mirrors, and concave lenses; (2) identifying the properties of light; and (3) determining the image distance, image location, and image properties on a convex lens. Stead also carried out the same research, and Osborne [8], whose results showed that many students thought that light was stationary (not propagated) or only propagated if it was in a bright place, the speed of light propagation did not depend on the light source but only on the light propagation medium. The difficulties experienced by students certainly result in low learning outcomes [5]. This is indicated by the GPA results obtained by prospective teacher students, which are less than three on average.

Based on the results of initial interviews with lecturers at a teacher teaching institution, four factors are suspected to be the cause of the difficulty of prospective physics teachers in understanding physics concepts, including (1) common understanding of abstract physics concepts; (2) the primary physics learning method applied seems informative and passive so that students are not trained to improve high-level critical thinking skills according to their competencies; (3) quizzes with structured feedback have never been carried out in introductory physics lectures; (4) students who take fundamental physics lectures are very heterogeneous in terms of initial abilities, learning speed, interest, and motivation to learn. In addition, the results of interviews with several prospective physics teacher students who have taken fundamental physics courses show that most students are challenged to solve problems, especially optical materials. They said that they were able or able to understand the material presented by the lecturer. Still, when they were given more complex visual material issues, they had difficulty determining the solution to the problem. This is undoubtedly an indication that the learning being carried out is still limited to the transfer of knowledge from lecturers to students, not how students learn to find concepts. This causes the concepts transferred to students to be short-lived and sustainable. As a result, students will have difficulty relating the concepts they have acquired to understand new physics concepts.

The level of the intellectual development of students in higher education is already at the level of high-level formal operations. According to Bloom's taxonomy (revised version), cognitive processes are divided into lower-order thinking and higher-order thinking. Students' ability at the low-level thinking level is the ability at the cognitive level to remember, understand and apply. In contrast, students' ability at the higher-order thinking level is the ability at the cognitive level to analyze, evaluate and create [9]. So, it can be said that higher-order thinking skills are also called Higher Order Thinking, namely the ability to analyze, evaluate, and create. According to Ref [10], higher-order thinking is; (1) thinking skills that are at the top of Bloom's cognitive taxonomy, (2) abilities whose teaching objectives behind the cognitive taxonomy can equip students to transfer knowledge, (3) part of thinking skills to apply the
knowledge and skills developed during learning in a new context. The new context in question is the application of concepts that students did not previously think about. Still, the concepts have been taught, so it is not necessarily something new universal. For students, higher-order thinking can also be interpreted as a student’s ability to connect concepts that have been learned with other things that have never been taught.

The relevant learning model to assist and facilitate and facilitate students in mastering the concepts of physics is the problem-based learning model. Through this learning model, students can develop thinking process skills [11]. According to Ref [12], the Problem Based Learning (PBL) model is a student-centered learning model that emphasizes collaboration in solving problems contextually. The problem-based learning model is considered to be able to help students in developing their ability to understand physics concepts because this model has the following characteristics: (1) The learning process starts from a problem related to student's daily lives, (2) Organize the concepts (materials) that are studied based on problems, not around scientific disciplines, (3) Train students to be responsible for shaping and carrying out the learning process directly and independently, (4) Presentation of learning in small groups, and (5) Guiding students to create products or performances from the concepts they have learned.

In other words, learning through the problem-based learning model begins with the disclosure of problems found in student life, where issues can be raised from students or lecturers. Then, students seek and determine methods to solve problems by deepening the knowledge and what needs to be known in solving problems. Problems so that they are motivated and active in learning. Issues that are used as the focus of learning can provide diverse learning experiences for students, such as collaboration and interaction in groups, in addition to learning experiences related to problem-solving such as making hypotheses, designing experiments, conducting investigations, collecting data, interpreting data, making conclusions—presenting, discussing, and making reports. In physics learning, especially optical material, problem-based learning models are expected to increase students' understanding of the relationship between knowledge about optics and the real world. Meanwhile, familiarize students with critical thinking and problem-solving skills, acquire essential knowledge and concepts from the subject matter, create a democratic classroom environment, and effectively deal with student diversity.

Based on the above background, the focus of the problems in this study are (1) Is there any effect of the application of the problem-based learning model on the ability of prospective physics teacher students to solve HOTS-based physics tests? (2) Is there an effect of critical thinking skills (high and low) on the ability of prospective physics teachers to solve HOTS-based physics tests? Moreover, (3) Is there an interaction between the application of problem-based learning models with critical thinking skills on the ability of prospective physics teachers to solve problems HOTS-based physics tests?

2. Method
The quasi-experimental design was used in this study. The participants of this study were 34 prospective physics teacher students at the 4th-semester level and attended fundamental physics courses. Participants were grouped into one experimental group of 19 people and one control group of 15 people. The experimental group was given treatment through Problem Based Learning, and the control group was assigned conventional learning. The two groups were also distinguished based on high and low critical thinking skills. The initial ability equivalence test of the experimental and control groups using the independent sample t-test showed that the initial abilities of the two groups were equivalent [13].

The technique used to collect data in this study is the test technique. The test technique measures students' ability to solve HOTS-based physics exam questions and students' critical thinking skills. The data collection tools used are (1) optical material HOTS-based exam questions in the form of two-level multiple choice (answer choices and reasons for choosing answers) with a total of 8 questions consisting of analyzing, evaluating, and creating questions; and (2) critical thinking ability test questions in the form of multiple-choice with a total of 30 questions. The test questions used in the research have gone through expert review and trials to determine the quality of the items. As a result, the criteria for the question instrument have met the valid criteria, high reliability, good discriminating power, and varying
levels of difficulty (difficult and moderate) [14]. Data on higher-order thinking skills and students' critical thinking skills were analyzed by inferential statistical tests, starting with the data normality test (Kolmogorov-Smirnov test) and the data homogeneity test (Levene Test) [15].

The different effects know two conditions of the implementation of problem-based learning and the conventional model and critical thinking skills (high and low). First, the parametric statistical test (t-independent) is used when the two-group data are distributed and homogeneous. However, if one of the conditions is not met, the data is analyzed using a non-parametric test (Mann Whitney U test) [16]. Second, based on the results of the homogeneity and normality of the data (Table 1 and Table 2), the comparative hypothesis test of higher-order thinking skills based on the treatment group was analyzed using parametric statistics (sample independent T-test). Meanwhile, the comparative hypothesis test based on critical thinking ability was analyzed using non-parametric statistics (Mann Whitney U Test). Analysis of the overall statistical test using IBM SPSS Statistics v.23 with an analysis scheme as shown in Figure 1.

![Figure 1. Schematic data analysis techniques for comparative and interaction tests of higher-order thinking skills based on instructional treatment groups and critical thinking ability](image)

### 3. Results and Discussion

#### 3.1 Result Data Analysis

The data obtained in the study are data on higher-order thinking skills and data on students' critical thinking skills. Data on higher-order thinking skills were measured using a two-tier multiple-choice test given to students after applying the problem-based learning model in the Experimental Group (EG) and applying the conventional model in the Control Group (CG). In contrast, data on critical thinking skills were measured by a multiple-choice test given before treatment. The data for higher-order thinking skills is presented in Figure 2. Based on Figure 2, it can be seen that the average ability of students in solving HOTS questions given learning using the problem-based learning model is higher than students who are taught using the conventional model.
Before the comparative hypothesis test, data on higher-order thinking skills were analyzed using the normality test (Kolmogorov-Smirnov test) and homogeneity test (Levene test) as prerequisites for determining the type of hypothesis statistics used. The results of the homogeneity test of higher-order thinking skills data by class (experiment-control) obtained a significance value of 0.542 (> = 0.05) which indicates that the data is homogeneous. Furthermore, data on higher-order thinking skills based on critical thinking ability (high-low) is also homogeneous (sig=0.356 > =0.05). The results of the data normality test are presented in Table 1.

**Table 1.** Results of data homogeneity test higher-order thinking skills (HOTS) based on the mean of treatment groups and critical thinking skills

| Data of HOTS                          | Levene Statistic | df₁  | df₂  | Sig. |
|--------------------------------------|------------------|------|------|------|
| based on treatment group (experiment-control) | 0.380            | 1    | 32   | 0.542|
| based on critical thinking ability (high-low)        | 0.877            | 1    | 32   | 0.356|

Table 2 shows that the data on higher-order thinking skills for both the experimental and control classes came from a population with a normal distribution (sig > 0.05). However, the critical thinking ability data in the high category was not normally distributed (sig < 0.05). Based on the results of the homogeneity and normality of the data (Table 1 and Table 2), the comparative hypothesis test of higher-order thinking skills based on the treatment group was analyzed using parametric statistics (sample independent T-test). Meanwhile, the comparative hypothesis test based on critical thinking skills was analyzed using non-parametric statistics (Mann Whitney U Test).

The hypotheses (Ho) in this study include: (a) there is no effect of the application of the problem-based learning model on the ability of prospective physics teacher students to complete the HOTS-based physics tests, (b) there is no effect of critical thinking skills (high and low) on the ability to student physics teacher candidates in solving HOTS-based physics tests, (c) there is no interaction between the application of problem-based learning models and critical thinking skills on the ability of physics teacher
candidates to complete HOTS-based physics tests. The summary of the results of the research hypothesis testing can be seen in Table 3 below.

| Source Data                  | Statistical Test     | Sig.  |
|------------------------------|----------------------|-------|
| Group Treatment (CT)         | T-independent sample test | 0.011 |
| Critical Thinking Ability (CTA) | Mann Whitney U Test     | 0.049 |
| Interaction CT*CTA           | F-Test               | 0.035 |

Based on Table 3, the significance value is less than 0.05 (α=5%), so it can be concluded that Ho is rejected (Ha is accepted). This means (a) there is an effect of applying the problem-based learning model on students' abilities in completing HOTS-based physics tests, (b) there is an influence of high critical thinking skills and low critical thinking skills on students' abilities in completing HOTS-based physics tests and (c) there is an interaction between the application of the problem-based learning model with critical thinking skills on the students' ability to complete the HOTS-based physics test.

3.2 Discussion

A problem-based learning model has a significant effect on students' higher-order thinking skills, in this case, the ability to solve HOTS-based questions, indicating that the application of problem-based learning models can improve students' higher-order thinking skills. This is in line with the research conducted by Ref [17]. His study concluded that the higher-order thinking ability of students taught by problem-based learning strategies was significantly higher than traditional learning. In addition, Students' ability to solve higher-order thinking questions after being taught using a problem-based learning model had good criteria for analyzing and evaluating and cannot create [18]. Students who experience a problem-based learning process have higher-order thinking skills. They can easily answer difficult physics questions in contrast to conventional learning models, where students are not less trained in constructing knowledge.

Students' average higher-order thinking ability is higher than the average higher-order thinking ability in classes taught with conventional models. The problem-based learning model requires students to carry out authentic investigations to find real solutions to real problems. Ref [19] revealed that students' high-level thinking patterns in problem-oriented situations, especially learning, can be supported through problem-based learning models. In the problem-based learning model, students are taught in five stages, starting from the student orientation stage on the problem. First, students are given problems that students often encounter in their real lives [20]. Issues are prepared as new learning contexts. Third, analysis and resolution of the problem result in the acquisition of knowledge and problem-solving skills. Issues are faced before all relevant knowledge is acquired, not only after reading a text or listening to a lecture on the subject matter behind the problem.

The second stage is to organize students to learn. The lecturer forms study groups of 3 to 4 people with different initial ability qualifications at this stage. This is so that students with high abilities can help their groupmates with moderate and low skills to form good teamwork. At this stage, group members have their respective roles in the group to have responsibilities within the group. The division of tasks in groups will increase student confidence. Students will be more flexible in expressing ideas or opinions when they feel needed in their groups [21]. Then each group discusses the solutions to the problems presented at the initial stage and plans the problem-solving procedures offered. When planning problem solving, students are trained to analyze the issues and find solutions to the problems given.

The third stage is guiding individual and group investigations. At this stage, each group investigates experiments for problem-solving. In conducting experimental activities, students are assisted with worksheets. At this stage, the lecturer encourages students to collect appropriate information through literature review, then conduct experiments to solve problems and get explanations from problem-solving.
The fourth stage is developing and presenting the work. Each group prepares the results of the experiments that have been carried out in the form of reports and products. The work is created collaboratively and independently by each group, which is then presented in front of the class and responded to by other groups. At this stage, students are trained to create a work by connecting the concepts they have with the concepts they found during learning so that students will be able to develop thinking skills at the level of creating.

The fifth stage is analyzing and evaluating the problem-solving process. Lecturers help students to reflect or assess their investigations and the methods they use. This stage trains students in evaluating all learning that has been done. This is evident from the results of student completion in solving HOTS questions, and it appears that students can plan and carry out problem-solving plans appropriately, understand the intent of the question correctly, and provide the right reasons/evidence so that the written answer will answer the question in question [22].

![Graph of Interaction between Instructional Treatment (EG/PBL Model and CG/Conventional Model) with Critical Thinking Ability (High and Low)](image)

**Figure 3.** Graph of Interaction between Instructional Treatment (EG/PBL Model and CG/Conventional Model) with Critical Thinking Ability (High and Low)

The results of the hypothesis test also show that critical thinking skills affect students' higher-order thinking skills. This means that students who have high critical thinking skills will be able to solve HOTS questions better than students who have low critical thinking skills after being taught with problem-based learning models. These results indicate an interaction between critical thinking skills and learning models applied in the classroom (Figure 3). According to Ref [19], critical thinking is a systematic and organized process that allows students to formulate and evaluate their own opinions and the evidence, assumptions, logic, and language that underlie other people's statements that they can ultimately solve. Problems encountered in everyday life. This means that students who have critical thinking skills tend to have systematic thinking patterns to go through the stages of analyzing, evaluating to the highest stage of creating in solving problems. The problem-based learning model is constructivist [23], so that students can learn to construct knowledge and apply the principles of physics when learning in class [24], and also students can improve their science process skills [25,26] and problem-solving skills [27,28] through this model.

4. Conclusions

The impact of the application of the problem-based learning model has been investigated for its effect on the ability of prospective physics teacher students to complete the HOTS-based physics test. The ability of prospective physics teacher students to complete the HOTS-based physics test is better after
the problem-based learning model is applied. Prospective physics teacher students with high critical thinking skills have better performance in completing HOTS-based physics tests. There is an interaction between the application of the problem-based learning model and the critical thinking skills of prospective physics teacher students in completing the HOTS-based physics test. Implementation of the problem-based learning model is essential for other physics materials. In addition to improving the understanding of physics concepts, it also enhances higher-order thinking skills for prospective physics teacher students.

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