IJORER : International Journal of Recent Educational Research
Homepage : https://journal.ia-education.com/index.php/ijorer
Email : ijorer@ia-education.com

p-ISSN : 2721-852X ; e-ISSN : 2721-7965
IJORER, Vol. 5, No. 1, January 2024
Page 77-89

Development of Problem-Based Learning Model Physics Learning Tools to Improve Critical Thinking Skills of High School Students

Arini Hidayati[1]*, Munasir[2], Elok Sudibyo[3]
[1,2,3] Universitas Negeri Surabaya, Surabaya, Indonesia

DOI: https://doi.org/10.46245/ijorer.v5i1.496

Sections Info

Article history:
Submitted: November 24, 2023
Final Revised: December 6, 2023
Accepted: December 19, 2023
Published: January 07, 2024

Keywords:
Critical Thinking Skills;
Physics Learning;
Problem-Based Learning Model.

ABSTRACT

Objective: This development research aims to produce physics learning tools with a quality Problem-Based Learning (PBL) model (validity, practicality, and effectiveness) to train students' critical thinking skills in Natural Resources and Environmental Conservation courses. **Method:** This research was carried out in several stages, namely developing tools using Thiagarajan's 4-D model and implementing learning tools during three meetings with 25 class A students and 26 class B students in the physics education study program of the Faculty of Natural Sciences. Mathematics and Natural Science State University of Surabaya's even semester program for the 2022/2023 academic year uses a one-group pretest-posttest design. **Results:** The research results were analyzed using descriptive analysis techniques. The feasibility of the learning plan in the good category is implemented. Student learning outcomes (knowledge, critical thinking, psychomotor, and attitudes) are completed classically. All students experienced increased critical thinking in the categories of unskilled-less skilled, then became unskilled-skilled, and rose again to unskilled-very skilled. Based on the results of learning observations in the form of student activities. **Novelty:** The novelty of this research lies in its new contribution to the field of education. Students gave positive responses to PBL model learning activities. This research shows that this approach is practical in developing it. Integrating critical thinking skills into problem-based learning provides essential added value in education. The research results show that physics learning tools use a valid, practical, and effective problem-based learning model to train students' critical thinking skills.

INTRODUCTION

Information technology's rapid development and progress cannot be separated from people's lives. Society now lives in the 21st century. The rapid development of information technology is a challenge for every individual. This, of course, will impact aspects of daily life, including the educational aspect. Critical thinking skills are a requirement for students in the 21st century to be ready to face competition, work, academics, and life. Several indicators of critical thinking skills in the 21st century that students must master are interpretation, analysis, evaluation, interference, explanation, and self-regulation (Aulia & Fida, 2023). Education must be considered and has a vital role in efforts to improve the quality of human resources so that they can compete from time to time (Priyono & Sinurat, 2020). The 21st century implies that individuals must have 4C competencies, namely Critical Thinking and Problem Solving, Creativity, Communication Skills, and Ability to Work Collaboratively (Arzak & Prahani, 2023; Neswary & Prahani, 2022; Pristianti & Prahani, 2022; Qotrunnada & Prahani, 2022; H. V. Saphira & Prahani, 2022)

The fields of technology and science, which are experiencing rapid progress, especially in education, increasingly emphasize the need for students to learn new, relevant skills

(Ani et al., 2023). These needs are the future of students after taking the educational path so that they can compete and produce strategic solutions to new problems in life (Chusni et al., 2020; Selman & Jaedun, 2020; Supena et al., 2021). Critical thinking is one of the skills discussed in various science types. This skill is considered an essential part of the overall problem-solving process. Besides, skills can be considered a foundation for developing personal and community competencies (Larsson, 2021). The scope of the problem is more specific, namely, in learning physics, critical thinking skills are needed to become a physicist. This is because scientific activities are closely related to science, especially physics; they cannot be separated from critical thinking activities, so that is one of the efforts. Making physics education and learning effective is by focusing on student's critical thinking skills (Sidiq et al., 2021)

Everyone needs critical thinking skills to deal with various personal and societal problems. Critical thinking is one of the 21st-century skills that are important for students to master to achieve maximum results in the learning process (Chusni et al., 2020; Hursen, 2021; Kardoyo et al., 2020; Lee, 2020). Students who are used to thinking critically will more quickly realize and pay attention to knowledge and processes in achieving learning goals. This makes students understand the material being studied. Critical thinking skills are demands that students must have in solving problems innovatively and systematically and designing solutions to face various future challenges (Prahani et al., 2023; Rizki et al., 2023; Saphira et al., 2022). The learning experience is obtained from learning activities carried out by students. Critical thinking skills improve the quality of one's thinking to be skilled in analyzing, assessing, and building something in one's mind to solve problems, so it is essential to develop. Critical thinking skills can be developed by providing students with direct experience in learning (Andriyani et al., 2019). Based on this, middle school-level students must have been trained to think at a higher level according to their age. Learners can be trained to be skilled at higher-order thinking by being trained on topics that invite students to think at the level of analysis, evaluation, and designing or producing work.

Critical thinking is a learning skill that must be taught to students because these skills are critical in life. In addition, the ability to think critically is a process that can be accepted by a rational, reflective, and responsible mind oriented to decisions about what to do or believe. In this case, it is not about analyzing random problems and arriving at conclusions, but the result of critical thinking is the best conclusion. The critical thinking skills of Indonesian students are still relatively low. This is known from the Program for International Student Assessment (PISA) results; Indonesia's literacy score is 382, ranking 64 out of 65 countries (Lentika & Admoko, 2022). The questions used consist of 6 levels (level 1 is the lowest, and level 6 is the highest). Students in Indonesia can only answer at levels I and 2. This shows that the ability of students to answer questions that refer to critical thinking skills still needs to improve. Such a learning process shows that learning problems cause students to have low critical thinking skills. Even though many learning practices have been used so far, they still need to improve students' critical thinking skills. The learning process could have been more optimal (Saputri, 2019).

Based on the results of the PISA research in mathematics, science, and reading organized by the Organization for Economic Cooperation and Development, Indonesia was ranked 64th out of 65 countries surveyed. The international assessment measures the skills of 15-year-old students in implementing their knowledge to solve real-world problems. The majority of Indonesian students have yet to reach level 2 for math (75.7%) and science (66.6%) (Gustiningsi et al., 2023; Harahap et al., 2021; Indrahadi & Wardana, 2020). More concerning, 42.3% of students have yet to reach the lowest level of proficiency (level 1) for mathematics and 24.7% for science. Life skills that must be developed during the educational process are thinking skills. Thinking is needed to develop attitudes and perceptions that support the creation of favorable classroom conditions, broaden knowledge, update relevant knowledge, and develop rational thinking behavior. The author made observations by giving critical thinking skills test questions to 51 Physics Education undergraduate students at Surabaya State University who had received material on environmental physics. Observation results show that of 25 students, it turns out that only 13 students are skilled and able to answer correctly; this indicates that students' ability to analyze various problems using thinking skills still needs to improve. The problems above, especially in the classroom, can be overcome with critical thinking skills. Training students to think critically through learning activities. Many approaches, strategies, methods, and models can be applied to train students' critical thinking learning; one option is to use a problem-based learning model (PBL).

PBL is a learning model requiring students' mental activities to understand a learning concept through authentic and meaningful situations and problems. The purpose of the PBL learning model is to train students to solve some problems using a problem-solving approach. The PBL model places more emphasis on solving problems through investigative activities. PBL presents various authentic and meaningful problematic situations to students, which serve as springboards for student investigations and investigations (Dila & Suyanto, 2023; Dinelti et al., 2022). Meanwhile, PBL is a learning model that presents various authentic and meaningful problem situations to students, which can serve as a springboard for investigation and inquiry. PBL model or problem-based learning is a learning model based on many problems that require authentic investigation, namely investigations that require real solutions to real problems. Learning that begins with a problem, students will try to deepen their knowledge of what is already known and what needs to be known to solve the problem. The PBL model is a learning model that can help students to be active and independent in developing thinking skills to solve problems through searching data so that rational and authentic solutions are obtained. The problems presented to students are problems of everyday life. Day or contextual.

In order to achieve the goals of education in the Independent Curriculum, namely to improve student achievement, train students' critical thinking skills through classroom learning, and see various real problems in education today, it is appropriate that learning patterns are oriented toward forming spiritual and social, intellectual attitudes. as well as problem-solving skills which are a reflection of critical thinking skills. To meet this expectation and given the lack of critical thinking learning tools, it is necessary to develop learning tools to teach students critical thinking skills, which are expected to become provisions for students' daily lives and future. In order for these goals and expectations to be implemented, the authors developed a learning tool that is oriented toward training students' critical thinking skills through the PBL model (Fitriani et al., 2022; Santos-Meneses et al., 2023; Sari & Prasetyo, 2021). Through the results of this learning design, there is great hope from the author to create learning situations that can improve students' critical thinking skills through a problem.

The novelty of this research lies in its new contribution to the field of education. Students gave positive responses to PBL model learning activities. Critical thinking ability is an essential skill in facing the challenges of the 21st century, and this research shows that this approach is practical in developing it. Integrating critical thinking skills into problem-based learning provides essential added value in education. Therefore, based on the background description above, the writer will conduct a study in teaching physics titled Development of Problem-Based Learning Model Tools to Improve Critical Thinking Skills.

RESEARCH METHOD

This research is a learning device development research. The tools developed include lesson plans, worksheets, and assessment sheets, designed using the PBL model to train students' critical thinking skills. The device development design follows a 4-D model design consisting of four stages: Define, Design, Develop, and Disseminate. This research was carried out in 3 stages: Define, Design, and Develop. This is due to time constraints and other supporting factors.

The test subjects for the device were S1 Physics Education students at the Faculty of Mathematics and Natural Sciences, Surabaya State University, in the even semester of the 2022/2023 academic year. The design of learning device trials in this development uses the One Group Pretest-Posttest Design model (Suyidno et al., 2017).

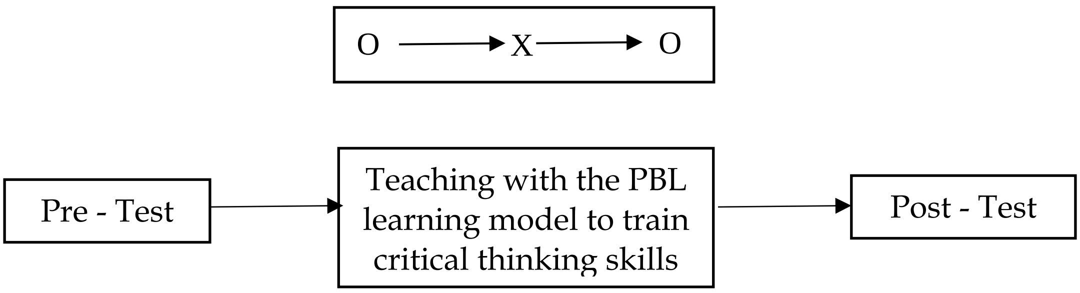

Figure 1. Research flowchart.

O1 Pre test
O2 Posttest
X PBL model learning treatment

Data validation results of learning tools were analyzed using a qualitative descriptive analysis. Data on the implementation of lesson plans, student activities, and student responses obtained were analyzed by qualitative descriptive analysis with percentages. Data on student learning outcomes is determined based on benchmark reference assessments. The critical thinking skills test results were analyzed using the critical thinking skills rubric with categories: 1) unskilled, 2) less skilled, 3) skilled, and 4) highly skilled. Data from the pretest and posttest results were then analyzed using N-gain with the criteria in Table 1.

Table 1. Criteria for interpretation of the N-gain value category.

N-gain (g)	Criteria
$0.7 \leq g$	High
$0.7 < g > 0.3$	Medium
$0.3 \geq g$	Low

Data was collected using the test, observation, and questionnaire methods. The test method is used to find out the results of students' critical thinking learning after participating in learning with the PBL model; the observation method is used to determine the implementation of learning student activities, and the questionnaire method is used to determine the validity of the device and student responses after participating in learning. Data validation results of learning tools were analyzed using a qualitative descriptive analysis. Data on the implementation of lesson plans, student activities, and student responses obtained were analyzed by qualitative descriptive analysis with percentages. Data on student learning outcomes is determined based on benchmark reference assessments. The critical thinking skills test results were analyzed using the critical thinking skills rubric with categories: 1) unskilled, 2) less skilled, 3) skilled, and 4) highly skilled. Data from the pretest and posttest results were then analyzed using N-gain.

Calculate the Percentage of Student Responses for Each Indicator using the following formula:

$$percentage\ (\%) = \frac{Number\ of\ respondent\ answer}{maximum\ score}\ x\ 100\%$$

The percentages calculated from student questionnaire responses are then represented in the scoring criteria as presented in Table 2.

Table 2. Representation of score.

N-gain (g)	Criteria
76.0% - 100.0%	Highly interesting
51.0% - 75.0%	Interesting
26.0% - 50.0%	Moderately interesting
0.0% - 25.0%	Not interesting

RESULTS AND DISCUSSION

Results

Learning Device Validity

Learning tools developed in this study include a lesson plan, student worksheet, and Assessment Sheet, then validated by a validator who is an expert in their field. The validation results can be seen in Table 3.

Table 3. Learning device validity.

Toolkit	Validity	Reliability
Lesson plan	3.7	87.0%
Student Worksheet	3.9	91.0%
The assessment sheet		
a. Learning Outcomes	3.6	90.0%
b. Critical Thinking Skills	3.9	90.0%
c. Psychomotor Skills	4.0	100.0%
d. Affective Skills	4.0	100.0%

In Table 1, the validator obtained the results of the validity assessment of the learning device. A learning device is said to be valid if the minimum score is 2.6 and is said to be reliable if the reliability value is 75.0%. Based on the value obtained from the validator, the device that has been developed is valid and reliable. The tools developed are designed with the PBL learning model, which begins with guiding and orienting students towards authentic problems, then organizing students in learning, helping students individually or in groups in carrying out research, developing and presenting work, and analyzing and evaluating the solution process problem (Arends, 2012; Seventika et al., 2018).

Implementation of the Learning Process

Two observer teachers observed the implementation of environmental physics learning with the PBL model, and the observer's assessment of the implementation of the PBL model learning obtained a mean score of 4.04 with the category well implemented. Students can solve questions by giving examples and practicing questions that use procedural knowledge. Students are faced with procedural knowledge involving several problems; students already experience difficulties in determining the variables that will be known.

Learning activities with the PBL model that have been carried out at meetings I, II, and III in phase 3: helping students individually or in groups in carrying out experiments, which in this phase requires much time and the teacher must be more intensive in guiding students because students are not familiar with developing hypotheses, determining control variables, manipulating variables, response variables and analyzing experimental data. In phase 3, students are also guided to formulate problems, make hypotheses, conduct experiments, analyze, and draw conclusions.

Student Activity

Two observers observe student activities that occur during the learning process. The aspects of student activity are as follows:

1. Reading (looking for information and so on)
2. Discuss the task
3. Take notes
4. Listen to the teacher's explanation
5. Make observations, experiments, or work
6. Pray according to religion and belief
7. Ask friends and teachers
8. Express opinions
9. Working together in groups
10. Behavior is irrelevant

Students have several main activities in the learning process, such as reading to find information, discussing assignments, making observations and experiments, asking teachers and friends, expressing opinions, and working together in groups. As much as 65.0% of study time is used to carry out these six activities. This shows that learning is focused on students.

Student Learning Outcomes

Student learning outcomes include tests of cognitive, psychomotor, and affective learning outcomes. The results of the completeness analysis of student learning outcomes in the cognitive aspect are 84.0%, 88.0% skills learning outcomes, and 100.0% attitude learning outcomes. The overall learning outcomes have individual completeness of 84.0%, and classically, it is said to be complete because the standard of classical completeness is

≥80.0%; this shows that the learning process using the PBL model has succeeded in making students achieve competency standards by achieving the expected indicators in the learning process. Knowledge learning outcomes at the implementation stage with individual completeness of 92.0% (23 students) were complete, and 8.0% (2 students) were incomplete. Two students who did not complete had knowledge test results with low scores; observations from observers of these students also showed low skill competence.

Observations that researchers made of these students needed more discipline; in 3 meetings, the students always came late and needed to be more enthusiastic in learning activities. The learning outcomes of attitudes observed in the learning process consist of spiritual and social attitudes. Spiritual attitudes include praying, saying greetings, giving thanks, and consistency between word and deed. Social attitudes include being honest and disciplined, providing arguments, asking and answering questions, and working in groups. Learning using the PBL model also supports aspects of skills and attitudes so that completeness can be realized because indicators of skills and attitudes are trained in learning.

Learning Outcomes of Critical Thinking Skills

The results of the critical thinking skills learning test during the pretest showed that all students were unskilled. After three learning meetings and a posttest, all students experienced changes in critical thinking skills. Students are considered thorough and skilled if they achieve a minimum score of 2.5. All students experienced changes in critical thinking skills, and the most significant change was in the unskilled category to become skilled. This increase occurred because learning using the PBL model motivated and facilitated students in practicing critical thinking skills. Changes in critical thinking skills can be seen in Table 4.

Table 4. Changes in students' critical thinking skills.

Change Critical Thinking Skills	**Trial**	
	Number of Students	**Percentage (%)**
Unskilled – Less Skilled	2	8.0%
Unskilled – Skilled	13	52.0%
Unskilled – Very Skilled	10	40.0%
amount	25	100.0%

The percentage change in critical thinking skills in Table 3 can be described in Figure 1.

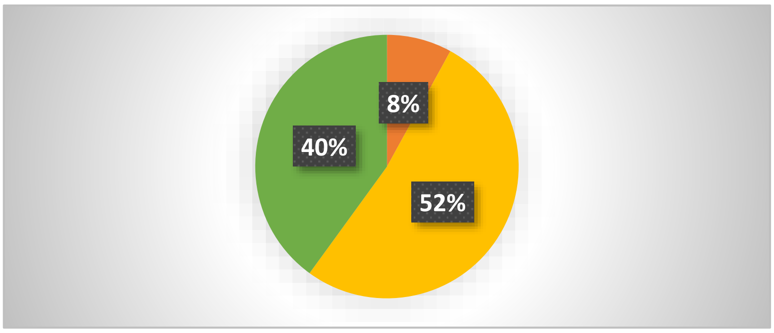

Figure 1. Changes in students' critical thinking skills.

In this research, we want to know whether the PBL model can train students' critical thinking skills. Screven and Paul (in Dennis, 2007) stated:

> "*Critical thinking is an intelligent disciplinary process of conceptualization, application, analysis, synthesis and active and skilled evaluation collected or generated by observation, experience, reflection, reasoning or communication as a guide to belief and action.*"

To train critical thinking skills, it is better in the learning process to involve students to think at a higher level, such as analyzing, synthesizing, predicting, and designing something in studying specific material or concepts. The learning model used in this research is the PBL model, which is allegedly able to train students' critical thinking skills. This is illustrated from each phase in the lesson plan with the PBL model, which requires students to think critically and logically in every step of the investigation, starting from formulating problems, formulating hypotheses, collecting data, compiling conclusions, and reflecting on the conclusions made. The prepared student worksheet also teaches students to carry out investigative steps with process skills and critical thinking skills.

Observing the existing research data, it is clear that students' critical thinking skills can only gradually solve a new problem. Critical thinking skills must be trained from various intelligent disciplinary processes in the learning stages. Critical thinking is the ability to think rationally and reflectively focused on what is believed or done. Rational means having beliefs and views supported by standard, actual, sufficient, and relevant evidence. Reflective means actively, diligently, and carefully considering before making a decision. Training students' critical thinking skills to a very skilled category, especially for students with a mental set inhibiting critical thinking, is not enough in just a few meetings; it takes a long time to get used to and train students' critical thinking skills. Two to three years to change students' mental sets that have long been formed so that students can integrate their ideas and apply critical thinking to new things. The results of the pretest and posttest of this study can be seen in Table 5.

Table 5. Student pretest and posttest data.

Description	Pretest	Posttest
Lowest	10.0	60.0
Highest	60.0	90.0
Average	29.2	72.4

The data in Table 5 shows that the posttest score is higher than the pretest score even though the posttest average score is still not by the provisions. This indicates that students' critical thinking skills have increased after giving treatment even though the overall value obtained has yet to reach the requirements because some students are constrained in working on questions in the HOTs category. One alternative solution so that the critical thinking skills of students who have been previously trained continue to develop and become more trained is to apply a learning model that can facilitate the development of critical thinking skills.

The N-gain test is carried out to describe the improvement of students' critical thinking skills after participating in environmental physics learning, which is carried out online with the Problem-based Learning model. The average results of the N-gain test in this study are presented in Table 6.

Table 6. N-gain test results.

Pretest Average	Posttest Average	N-gain	Category
29.2	72.4	0.6	Medium

Table 6 is the N-gain result of this study's sample data, which indicates an increase in students' critical thinking skills after participating in learning activities using the PBL model. The results of the N-gain of the sample data for this study were 0.6 and were at a moderate level. Students' critical thinking skills have increased to a moderate level, with an N-gain score of 0.6 after applying the PBL model.

Discussion

Student Response

Most students responded positively to learning with the PBL model to practice critical thinking skills. This means students are interested in learning with the PBL model applied to learning environmental physics. This interest is expected to encourage, inspire, and familiarize students with using problems or getting used to responding to and solving everyday problems. A summary of student responses can be seen in Table 7.

Table 7. Student responses to the PBL model learning.

Student Response	Opinion Response			
Interest learning component	Very Interested 52.0%	Moderately Interested 40.0%	Less Interested 8.0%	Not Interested -
Up-to-date learning components	Very New 44.0%	Fairly New 48.0%	Less New 4.0%	Not New 4.0%
Ease of understanding the learning component	Very Easy 24.0%	Fairly Easy 56.0%	Less Easy 16.0%	Not Easy 4.0%
Teacher/lecturer guidance and explanation	Very clear 60.0%	Sufficiently clear 32.0%	Unclear 8.0%	Not clear 0.0%
Critical thinking skills	Very Easy 16.0%	Moderately Easy 56.0%	Difficult 24.0%	Very Difficult 4.0%

This response shows that students can accept all learning components well, including student books, worksheets, learning materials, learning atmosphere, and how the teacher/lecturer teaches. This shows that at each meeting, students use teaching materials as a basis for searching for information to complete assignments, problems, experimental questions, and experiments contained in student worksheets. Student responses to the critical thinking component yielded results. There were still students who stated that it was difficult to develop critical thinking skills, but most students stated that it was pretty easy to learn and understand critical thinking skills; this means that students are interested in learning with the PBL model to train critical thinking skills for applied in learning physics.

In the PBL model learning activities, students become the center of attention and are actively involved in the learning process, not just passive recipients of information from the teacher. PBL requires students to interact with groups, connect learning with other content, and train students' abilities to ask questions, find the right solutions, and think critically. Therefore, PBL consistently supports physics learning because it provides steps for students to solve physics problems in everyday life by using physics concepts (Hidaayatullaah et al., 2020; Samadun & Dwikoranto, 2022). In the PBL model, the teacher presents interesting problem situations at the beginning of learning to arouse students' interest in identifying problems. Then, the teacher helps organize students' cooperative skills to study minor research group problems, collect and experiment with data, develop hypotheses, present solutions, visualize problem-solving processes, analyze, and evaluate.

PBL learning is based on the backgrounds, expectations, and backgrounds of the students' objects of interest. This is because students are motivated to work harder compared to the PBL model with traditional teaching methods. Students generally spend more time learning when they work with the PBL model. Student participation is much greater because there is a relationship between them. Teaching methods, depth, and complexity of learning Students are expected to achieve a complex level of analytical understanding through the work of a project, which is not possible in an ordinary classroom. The most important part of learning PBL is ensuring students can explore all its possibilities for their future lives (Pan et al., 2021; Rohm et al., 2021).

CONCLUSION

Fundamental Finding: Based on the results of testing the device, analysis, discussion, discussion, and research findings, in general, it can be concluded that the PBL model environmental physics learning tool developed is valid, practical, and effective for training students' critical thinking skills. The advice that can be given regarding the development of this device is that further study is needed, taking into account time so that it takes a short time. **Implication:** Some of these findings have significant implications for the world of education. Improving critical thinking through Problem-Based Learning shows its value in fostering scientific development. Teachers should consider incorporating this approach into the curriculum. Positive student feedback is critical in creating an exciting and motivating learning environment to encourage creativity.

In conclusion, this research underlines the need for more contextual and interactive education, focusing on critical thinking to prepare students for the future. **Limitation:** In summary, this research shows the success of the Problem-Based Learning model in improving students' critical thinking skills, as evidenced by the average N-Gain score at a medium level. Positive student responses further emphasize the effectiveness of this method in increasing motivation, understanding, and real-world connections. **Future Research:** Meanwhile, further research can explore contextual variables and their impact on the effectiveness of the PBL model in improving critical thinking skills. Comparison with other teaching methods and models, long-term evaluation, and curriculum development are also relevant research areas.

ACKNOWLEDGEMENTS

Acknowledgments to the Internship Team: Thank you for your enthusiasm, knowledge, and expertise in helping me research and write this article. To the Supporting Lecturers, thank you for the guidance and direction. I want to thank the 2022 Unesa Physics Education undergraduate students who have made valuable contributions through participation and collaboration in this research. I appreciate the passion for learning and the collaborative spirit you showed. Your hard work and dedication have positively impacted the outcome of this article.

REFERENCES

Andriyani, A., Sulistiyorini, S., & Arik, A. (2019). A digital trigonometry module based on discovery learning and critical thinking skills. *AIP Conference Proceedings Biophysics & Bioengineering Collection*, 1-5. https://doi.org/10.1063/5.0155194

Ani, R., Ridho, A. N., Mahardika, M., Bambang, S. (2023). Development of waves critical thinking test: Physics essay test for high school student. *European Journal of Educational Research, 12*(4), 1781 - 1794. https://doi.org/10.12973/eu-jer.12.4.1781

Arends, I. R. (2012). *Learning to teach*. McGraw-Hill.

Arzak, K. A., & Prahani, B. K. (2023). The physics problem solving skills profile of high school students in elasticity material and the implementation of augmented reality book-assisted PBL model. *Momentum: Physics Education Journal, 7*(1), 1–15. https://doi.org/10.21067/mpej.v7i1.6704

Aulia, S. N., & Fida, R. (2023). Development of PBL based e-books in environmental change topic to train critical thinking skills of 10th grade students in senior high school. *Jurnal Bioedu Berkala Ilmiah Pendidikan Biologi, 12*(2), 321-342.

Chusni, M. M., Saputro, S., Suranto, S., & Rahardjo, S. B. (2020). Review of critical thinking skill in Indonesia: Preparation of the 21st century learner. *Journal of Critical Reviews, 7*(9), 1230–1235. https://doi.org/10.31838/jcr.07.09.223

Dennis. F. K, (2007). *Menguak rahasia berpikir kritis dan kreatif.* Prestasi Pustakarya.

Dila, E. F., & Suyanto, S. (2023). The effect of problem based learning models with question cards on environmental pollution materials on problem solving ability, scientific attitudes, and student learning outcomes. *Jurnal Pendidikan Sains Indonesia, 11*(4), 884–896. https://doi.org/10.24815/jpsi.v11i4.32480

Dinelti, F., Lufri, L., Imran, A., & Ahda, Y. (2022). Studi literature model problem based learning. *International Journal Of Humanities Education and Social Sciences (IJHESS), 1*(6), 908–920. https://doi.org/10.55227/ijhess.v1i6.177

Fitriani, H., Samsuri, T., Rachmadiarti, F., Raharjo, R., & Mantlana, C. D. (2022). Development of evaluative-process learning tools integrated with conceptual-problem-based learning models: Study of its validity and effectiveness to train critical thinking. *International Journal of Essential Competencies in Education, 1*(1), 27–37. https://doi.org/10.36312/ijece.v1i1.736

Gustiningsi, T., Ilma, R., & Putri, I. (2023). Developing a PISA-like mathematical problem : Using traditional food context. *International Journal of Education & Curriculum Application, 6*(3), 324–337. https://doi.org/10.31764/ijeca.v6i3.20200

Harahap, K. A., Sinaga, B., & Siagian, P. (2021). Development of geogebra-assisted problem based learning (PBL) learning tools to improve visual thinking skills in mathematical problem solving students of SMA negeri 1 samudera. *Budapest International Research and Critics in Linguistics and Education (BirLE) Journal, 4*(1), 239–251. https://doi.org/10.33258/birle.v4i1.1581

Hidaayatullaah, H. N., Dwikoranto, Suprapto, N., Mubarok, H., & Wulandari, D. (2020). Implementation of problem based learning to train physics students' problem solving skills. *Journal of Physics: Conference Series, 1491*(1), 1-8. https://doi.org/10.1088/1742-6596/1491/1/012053

Hursen, C. (2021). The effect of problem-based learning method supported by web 2.0 tools on academic achievement and critical thinking skills in teacher education. *Technology, Knowledge and Learning, 26*(3), 515–533. https://doi.org/10.1007/s10758-020-09458-2

Indrahadi, D., & Wardana, A. (2020). The impact of sociodemographic factors on academic achievements among high school students in indonesia. *International Journal of Evaluation and Research in Education, 9*(4), 1114–1120. https://doi.org/10.11591/ijere.v9i4.20572

Kardoyo, K., Nurkhin, A., Muhsin, M., & Pramusinto, H. (2020). Problem-based learning strategy: Its impact on students' critical and creative thinking skills. *European Journal of Educational Research, 9*(3), 1141–1150. https://doi.org/10.12973/EU-JER.9.3.1141

Larsson, K. (2021). Using essay responses as a basis for teaching critical thinking: A variation theory approach. *Scandinavian Journal of Educational Research, 65*(1), 21–35. https://doi.org/10.1080/00313831.2019.1650824

Lee, E. (2020). Student's critical thinking skills through discovery learning model using e-learning on environmental change subject matter. *European Journal of Educational Research, 9*(3), 921–934. https://doi.org/10.12973/eu-jer.10.3.1123

Lentika, D. L., & Admoko, S. (2022). Development of newton gravity student worksheets on problem-based learning model to improve students' scientific argumentation skills. *Prisma Sains : Jurnal Pengkajian Ilmu Dan Pembelajaran Matematika Dan IPA IKIP Mataram, 10*(3), 556–566. https://doi.org/10.33394/j-ps.v10i3.5349

Neswary, S. B. A., & Prahani, B. K. (2022). Profile of students' physics critical thinking skills and application of problem based learning models assisted by digital books in physics learning in high school. *Jurnal Penelitian Pendidikan IPA, 8*(2), 781–789. https://doi.org/10.29303/jppipa.v8i2.1444

Pan, G., Seow, P.-S., Shankararaman, V., & Koh, K. (2021). An exploration into key roles in making project-based learning happen. *Journal of International Education in Business, 14*(1), 109–129. https://doi.org/10.1108/JIEB-02-2020-0018

Prahani, B. K., Saphira, H. V., Jatmiko, B., Dwikoranto, D., Amelia, T., Muslimin, M., Khuddus, L. A., & Bergsma, L. N. (2023). Research trends of pre-service physics teachers' critical thinking skills during 2001 to 2022. *International Journal of Emerging Research and Review*, *1*(2), 1-11. https://doi.org/10.56707/ijoerar.v1i2.2

Pristianti, M. C., & Prahani, B. K. (2022). Profile of students' physics problem solving skills and problem based learning implementation supported by website on gas kinetic theory. *Jurnal Pendidikan Progresif, 12*(1), 375–393. https://doi.org/10.23960/jpp.v12.i1.202229

Priyono, P., & Sinurat, S. (2020). Communication dan collaboration sebagai implementasi 4c dalam kurikulum 2013 di pondok pesantren el alamia bogor. *Research and Development Journal of Education*, *6*(2), 1-12. http://dx.doi.org/10.30998/rdje.v6i2.6228

Qotrunnada, N. A., & Prahani, B. K. (2022). Profile of PBL model assisted by digital books to improve problem solving ability of high school students on dynamic fluids. *Jurnal Penelitian Pendidikan IPA, 8*(3), 1175–1183. https://doi.org/10.29303/jppipa.v8i3.1451

Rizki, I. A., Saphira, H. V., Alfarizy, Y., Saputri, A. D., Ramadani, R., & Suprapto, N. (2023). Adventuring physics : Integration of adventure game and augmented reality based on android in physics learning. *International Journal of Interactive Mobile Technologies (IJIM), 17*(1), 4–21. https://doi.org/10.3991/ijim.v17i01.35211

Rohm, A. J., Stefl, M., & Ward, N. (2021). Future proof and real-world ready: The role of live project-based learning in students' skill development. *Journal of Marketing Education, 43*(2), 204–215. https://doi.org/10.1177/02734753211001409

Samadun, S., & Dwikoranto, D. (2022). Improvement of student's critical thinking ability sin physics materials through the application of problem-based learning. *IJORER : International Journal of Recent Educational Research, 3*(5), 534–545. https://doi.org/10.46245/ijorer.v3i5.247

Santos-Meneses, L. F., Pashchenko, T., & Mikhailova, A. (2023). Critical thinking in the context of adult learning through PBL and e-learning: A course framework. *Thinking Skills and Creativity*, *49*, 1-12. https://doi.org/10.1016/j.tsc.2023.101358

Saphira, H. V., & Prahani, B. K. (2022). Profile of senior high school students' critical thinking skills and the need of implementation PBL model assisted by augmented reality book.

Jurnal Pendidikan Sains Indonesia, 10(3), 579–591. https://doi.org/10.24815/jpsi.v10i3.25031

Saphira, H. V., Rizki, I. A., Alfarizy, Y., Saputri, A. D., Ramadani, R., & Suprapto, N. (2022). Profile of students ' critical thinking skills in physics learning : a preliminary study of games application integrated augmented reality. *Journal of Physics: Conference Series, 2377*, 1-7. https://doi.org/10.1088/1742-6596/2377/1/012088

Saputri, A. C., Sajidan, S., Rinanto, Y., Prasetyanti, N. M. (2019). Improving students' critical thinking skills in cell-metabolism learning using stimulating higher order thinking skills model. *International Journal of Instruction, 12*(1), 327-342.

Sari, D. M. M., & Prasetyo, Y. (2021). Project-based-learning on critical reading course to enhance critical thinking skills. *Studies in English Language and Education, 8*(2), 442–456. https://doi.org/10.24815/siele.v8i2.18407

Selman, Y. F., & Jaedun, A. (2020). Evaluation of the implementation of 4C skills in indonesian subject at senior high schools. *Jurnal Pendidikan Indonesia, 9*(2), 244–257.

Seventika, S. Y., Sukestiyarno, Y. L., & Mariani, S. (2018). Critical thinking analysis based on Facione (2015) - Angelo (1995) logical mathematics material of vocational high school (VHS). *Journal of Physics: Conference Series, 983*(1), 1–6. https://doi.org/10.1088/1742-6596/983/1/012067

Sidiq, Y., Ishartono, N., Desstya, A., Prayitno, H. J., Anif, S., & Hidayat, M. L. (2021). Improving elementary school students'critical thinking skill in science through hots-based science questions: A quasi-experimental study. *Jurnal Pendidikan IPA Indonesia, 10*(3), 378–386. https://doi.org/10.15294/JPII.V10I3.30891

Supena, I., Darmuki, A., & Hariyadi, A. (2021). The influence of 4C (constructive, critical, creativity, collaborative) learning model on students' learning outcomes. International *Journal of Instruction, 14*(3), 873–892. https://doi.org/10.29333/iji.2021.14351a

Suyidno, S., Nur, M., Yuanita, L., Prahani, B. K., & Jatmiko, B. (2017). Effectiveness of creative responsibility based teaching model on basic learning physics to increase student's scientific creativity and responsibility. *Journal Baltic Science Education, 17*(1), 136–151. http://dx.doi.org/10.33225/jbse/18.17.136

***Arini Hidayati, S.Pd. (Corresponding Author)**
Postgraduate Department of Science Education,
State Universityof Surabaya,
Jl. Ketintang Building D1 Surabaya, East Java, 60231, Indonesia
Email: arini.22005@mhs.unesa.ac.id

***Prof. Dr. Munasir, M.Si.**
Postgraduate Department of Science Education,
State Universityof Surabaya,
Jl. Ketintang Building D1 Surabaya, East Java, 60231, Indonesia
Email: munasir_physics@unesa.ac.id

***Dr. Elok Sudibyo, M.Pd.**
Postgraduate Department of Science Education,
State Universityof Surabaya,
Jl. Ketintang Building D1 Surabaya, East Java, 60231, Indonesia
Email: eloksudibyo@unesa.ac.id