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Problem-Based Learning Based on Coastal Abrasion Cases to Improve Conceptual Understanding and Problem-Solving Ability

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Abstract: Problem-solving ability is one of the higher-order thinking skills that students must possess, as it enables them to apply scientific knowledge to real-life situations. This study aimed to investigate the effect of problem-based learning (PBL), based on coastal abrasion cases, on improving students' conceptual understanding and problem-solving ability. A quasi-experimental method with a pretest-posttest control group design was employed. The research was conducted in two classes: the experimental class used PBL, while the control class applied Discovery Learning. The sample consisted of 60 students. Instruments included tests designed to measure both conceptual understanding and problem-solving ability. Data were analysed using ANOVA. The results showed that the significance value was less than 0.05. This indicates that students who received PBL instruction achieved significantly higher scores in conceptual understanding and problem-solving ability than those taught using Discovery Learning. These findings suggest that PBL based on real-world issues, such as coastal abrasion, is effective in enhancing students' scientific thinking and problem-solving skills.

Keywords: Coastal abrasion; Conceptual understanding; Problem-based learning; Problem-solving ability

Introduction

The current learning goals emphasise students' ability to understand scientific concepts and apply them in real-life situations through problem-solving. These two competencies—conceptual understanding and problem-solving skills—are fundamental to 21st-century learning and must be developed early to equip students for global competition (Ariyanti & Yulianti, 2019; Latifah & Azizah, 2020; Ling & Mahmud, 2023; Aryani & Wahyuni, 2023). Students must be trained to solve real-world problems by applying scientific knowledge, especially in everyday environmental issues (Fakhruddin, 2019; Zhao & Allen, 2023; Wahyudi et al., 2024).

One of the most relevant contexts for developing these skills is environmental change, which is studied in Grade X of high school in the even semester. This topic aims to help students analyse and solve environmental problems. However, findings from preliminary observations indicate that the learning process in this area remains largely theoretical. Students are not yet trained to engage in problem-solving processes that involve identifying real issues, formulating hypotheses, investigating evidence, and applying integrated scientific concepts to propose solutions. In particular, classroom instruction often fails to use contextual and local environmental issues that students can relate to, such as coastal abrasion, one of the most visible and impactful environmental changes in many coastal regions.

This disconnect between curriculum goals and classroom practice results in students' limited reasoning abilities when facing problems that require them to connect multiple scientific concepts (Ulhaq et al., 2024). Consequently, students struggle to engage in higher-

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order thinking and to demonstrate mastery of scientific knowledge in practical contexts.

Therefore, this study examined the effectiveness of problem-based learning (PBL), using real cases of coastal abrasion, in enhancing students' conceptual understanding and problem-solving abilities. By integrating local environmental issues into PBL, this research aims to make science learning more meaningful, contextual, and aligned with students' cognitive development and real-world challenges. The problem-solving abilities of students in Indonesia are still below average, and they have not been able to understand the problem and review the problem given, so they have not been able to find the right solution (Haming & Nurhayati, 2024). Mastery of concepts is the main capital for developing students' problem-solving abilities (Chamidy et al., 2020). Therefore, problem solving abilities must be improved to build knowledge and creativity. Students must be involved in the learning process and tasks related to problem solving. One effort that can be made is to apply the problem-based learning (PBL) model and present real cases that occur around students (Thomas, 2000; Savery, 2006; Bell, 2010; Hasibuan, 2020; Nugraheni & Wilujeng, 2020; Rahayu & Anggraini, 2020).

The PBL model involves students actively in problem solving activities through reasoning, investigating, discussing, finding solutions and evaluating solutions in solving problems so that they become students who think critically (Özdeniz et al., 2023). Presenting problems in PBL learning can stimulate students to find solutions and decide on the most appropriate solution to solve the problem (Mustofa & Hidayah, 2020). The characteristics of learning using the PBL model make students more active and independent in discovering knowledge concepts and connecting this knowledge with real problems presented in learning.

One of the common environmental problems faced by Indonesia as an archipelagic country is coastal erosion due to large waves hitting the shoreline, causing it to gradually erode. Apart from that, various human activities can also worsen the impact of coastal erosion, such as cutting down mangroves, sand mining, destroying coral reefs, and development activities on the coast (Diposaptono, 2011).

The PBL learning model based on coastal abrasion cases will develop critical thinking skills in problem solving and increase awareness of the surrounding environment. Students' knowledge is built based on their thinking, and teachers are tasked with reflecting on students' thinking. Several previous studies have shown the success of the PBL model in increasing conceptual understanding (Putri et al., 2018; Nainggolan et al., 2023) and students' problem-solving abilities through active involvement in learning (Lubis, 2020; Ichsan et al., 2023). This research must be carried out to see the impact of PBL based on coastal abrasion cases on students' conceptual understanding and problem-solving abilities.

Method

This research approach is quantitative and quasi-experimental, with pre-test and post-test group design (Arikunto, 2020; Creswell, 2014). The research was carried out in Sebatik, North Kalimantan in the even semester of the 2023-2024 academic year.

The population of this study was 383 phase E high school students in Sebatik. The sampling technique is Cluster Random Sampling. Sampling was carried out by randomization of groups, not individual subjects. The sample in this study consisted of 2 classes totaling 60 students, namely 30 students from class X-D SMAN 1 Sebatik Tengah in the control class and 30 students from class X-B SMAN 1 as the experimental class sample.

Table 1. Pretest-posttest control group design

Class	Pretest	Treatment	Posttest
Experiment	O1	X1	O2
Control	O3	-	O4

Information:
O1 : pretest score experimental group
O2 : posttest score experimental group
O3 : pretest score control group
O4 : posttest socre control group
X1 : Problem Based Learning model
- : Discovery Learning model

The ability to understand concepts and problem solving abilities is obtained through written tests in the form of essay questions. The concept understanding instrument is based on indicators of achieving learning objectives, including: analyzing the causes and negative impacts of coastal environmental change; analyzing the relationship between human behavior and the problem of coastal environmental change; formulating solution ideas. The question instrument has been validated by experts and empirical validation has been carried out. Criteria for achieving learning objectives for students can be seen in Table 2.

Table 2. Criteria for achieving learning objectives

Score Interval	Criteria
0-60	Inadequate
61-70	Haven't reached completion yet
71-80	Has reached completion
81-100	Has reached completion

Source: Kemendikbud (2022)

The problem-solving ability questions were designed based on indicators of problem-solving ability, including: understand the problem, prepare a plan, solve problems, and evaluate (Wahyuni & Astuti, 2021; Ulhaq et al., 2024). Criteria for students' problem solving abilities can be seen in Table 3.

Table 3. Criteria for students' problem solving abilities

Problem-solving abilities score	Criteria
80-100	Very high
60-79	High
40-59	Enough
20-39	Low
0-19	Very low

Source: Surif et al. (2012)

Result and Discussion

Measuring concepts understanding is carried out using a description test given to students at the beginning and end of learning to determine their improvement. The results of students' concept understanding before and after learning can be seen in Table 4.

Table 4. Results of descriptive analysis of pretest and posttest students' conceptual understanding

Description	Experiment		Control	
	Pretest	Posttest	Pretest	Posttest
N	30	30	30	30
Maximum	67	93	67	80
Minimum	47	73	40	60
Average	55	78	54	70

The average pretest score for conceptual understanding from the two classes showed results that were not much different. Then, after being given treatment, the average posttest score for the experimental class using the PBL model was higher than the control class using the Discovery Learning model. Experimental class students got a minimum score of 73, meaning that all experimental class students achieved the learning objectives.

Measuring problem-solving ability is done using a description test given to students at the beginning and end of learning to determine their improvement. The results of students' problem-solving ability before and after learning can be seen in Table 5.

The average pretest score for problem solving abilities from the two classes shows results that are not much different. Then, after being given treatment, the average posttest score for the experimental class that used the PBL model was higher than the control class that used the Discovery Learning model. Experimental class students got a minimum score of 75, meaning that all experimental class students had problem solving abilities in the high and very high categories.

Table 5. Results of descriptive analysis of pretest and posttest students' problem-solving ability

Description	Experiment		Control	
	Pretest	Posttest	Pretest	Posttest
N	30	30	30	30
Maximum	75	92	67	83
Minimum	50	75	42	66
Average	58	80	52	70

Data were analyzed using the ANOVA test formula to see the effect of treatment on concept understanding. Based on ANOVA Test of the PBL Model on Concept Understanding, a sig value of $0.000 < 0.05$ is obtained, which means there is a significant difference between the average concept understanding of the experimental and control class. This significant difference shows that the application of the PBL learning model has an influence on high school students' conceptual understanding of the subject of environmental change based on coastal abrasion cases.

There is an increase in conceptual understanding because in the PBL model learning process, students not only focus on absorbing information, but also actively discuss problem solving. Students are faced with real and relevant situations or problems, PBL encourages them to explore existing knowledge, seek new information, and apply the concepts they have learned in real contexts. This problem-based learning process not only increases student involvement, but also allows them to understand concepts in more depth because they have to consider various aspects in solving problems (Loyens et al., 2015).

Research conducted by Putri et al. (2018) proves that the PBL model has a factually significant effect on increasing mastery of concepts in each cognitive domain, especially in cognitive domains C3-C4. C3 is related to the application of concepts, while C4 is related to analysis. This proves that the problem solving model encourages students to have higher thinking skills such as analyzing and applying.

To understand the meaning, students must master the concepts in learning. They must be able to express material in a way that is easy to understand, provide interpretation, and apply. Innovative and problem-based learning models can be used to increase students' conceptual understanding. In addition, learning tools that optimally utilize students' thinking processes can be used to improve their ability to understand concepts (Barrows, 1986; Ruseffendi, 2006; Joyce et al., 2009; Mulyasa, 2009; Tjalla, 2010; Ihsani et al., 2020).

PBL syntax, which emphasises solving real-world problems through collaboration, investigation, and

reflection, effectively encourages students to develop a deep understanding of the subject matter. By actively participating in a learning process that requires problem solving, students gain knowledge of facts and understand concepts as a whole and develop critical and analytical skills. According to Hmelo-Silver (2004) and Hendriana et al. (2018) confirmed that implementing PBL is consistently associated with increasing students' conceptual understanding in various disciplines.

Based on a sig value of 0.000 < 0.05, there is a significant difference between the average problem-solving abilities of the experimental and control classes. This significant difference shows that applying the PBL learning model affects the problem-solving abilities of high school students on the subject of environmental change based on coastal abrasion cases.

There is an increase in students' problem-solving abilities because the PBL model effectively encourages students to actively participate in discussions and improves students' problem-solving skills and creativity (Assegaff & Sontani, 2016).

According to Rubini et al. (2019), PBL is designed to help students develop thinking skills, problem solving skills and other intellectual skills. If students are trained to solve problems in learning, then students will be able to solve problems in a wider scope, namely in the real world. According to Kaus et al. (2017), problem-solving activities involve recognising problems and determining strategies to complete certain tasks given to students. Therefore, the ability to solve problems is an important part of designing a science learning curriculum. According to Ginting (2021), the ability to solve problems is one of the main goals in the educational process.

Conclusion

The results of data analysis and discussion conclude that the application of the PBL model based on coastal abrasion cases can increase conceptual understanding and train students' problem solving abilities which consist of formulating identifying problems, formulating problems, organizing information, finding solutions, and choosing solutions. This can be seen from the students' problem solving ability scores which have increased to the high category.

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Author Contributions
N.F.: Led the research design, developed the learning model integrating problem-based learning (PBL) with coastal abrasion cases, conducted data collection and analysis, and drafted the manuscript. She ensured the integration of scientific content and learning outcomes by curriculum standards; S.A.: Contributed to developing the research methodology, especially in aligning PBL with scientific inquiry. He supervised the study's implementation, ensured the instruments' validity, and provided critical review and refinement of the manuscript; W.: Provided contextual insights related to ecological citizenship and environmental awareness in border areas, ensuring the relevance of coastal abrasion as a real-life case in civic and environmental education. He contributed to the discussion by connecting the development of students' problem-solving skills with the formation of responsible ecological citizens, particularly in vulnerable coastal and frontier communities.

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