



The Effect of a Problem-Based Learning Model Assisted by Augmented Reality on the Computational Thinking Skills of Grade XI Students at SMAN 1 Labuapi

Diyah Nurmayanti¹, Mahrus¹, Sambrean akram², Roshiya Hilyatyi³, Wilia Lara Ervantira⁴

¹Master of Science Education Program, University of Mataram, Mataram, Indonesia;

² Department of Botany, Faculty of Basic Sciences, University of Chakwal, Punjab, Pakistan;

³ Tadris Biology (Science Education), Faculty of Tarbiyah and Teacher Training, State Islamic University of Mataram, Indonesia;

⁴Veterinary Medicine Study Program, Udayana University, Bali, Indonesia.

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*Corresponding Author

Diyah Nurmayanti,

University of Mataram, Indonesia;

E-mail:

diyahnurmayanti456@gmail.com

Abstract

The rapid development of science and technology requires students to possess computational thinking skills as part of 21st-century competencies. This study aims to determine the effect of the Problem-Based Learning model assisted by Augmented Reality on the computational thinking abilities of grade XI students. This research employed a quasi-experimental design with a nonequivalent control group, involving experimental and control classes at SMAN 1 Labuapi. The results showed that the average pretest scores of the experimental and control classes were relatively similar (45.20 and 46.80), while the posttest results indicated a significant improvement in the experimental class (74.50) compared to the control class (58.30). Hypothesis testing confirmed that the implementation of Problem-Based Learning, assisted by Augmented Reality, had a significant effect on students' computational thinking skills, as evidenced by higher corrected mean scores in the experimental class (67.620) than in the control class (46.130). In conclusion, integrating Problem-Based Learning with Augmented Reality effectively enhances students' computational thinking abilities. This study suggests that innovative learning models integrated with technology can be used to improve higher-order thinking skills in biology.

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Keywords: problem-based learning; augmented reality; computational thinking; biological literacy; biology education



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INTRODUCTION

The advancement of science and technology requires human resources to possess 21st-century skills, one of which is computational thinking. Computational thinking refers to the ability to solve problems systematically through four main stages: decomposition, pattern recognition, abstraction, and algorithm design (Cynthia & Sihotang, 2023). In the context of Grade XI biology learning, these four stages can be explicitly integrated into the digestive system topic. For instance, students can apply decomposition by breaking down the digestive system into its constituent organs and functions, such as the mouth, stomach, small intestine, and large intestine. Pattern recognition can be implemented by identifying recurring mechanisms by which digestive enzymes act on specific substrates. Abstraction involves simplifying the digestion process into a flow scheme from ingestion to defecation. Meanwhile, algorithm design can be applied by constructing systematic steps for analyzing digestive disorders, such as gastritis or malabsorption.

These skills are essential because they enable students to process biological information logically and efficiently when tackling complex problems in the digital era. Furthermore, computational thinking aligns with deep learning, an instructional approach that emphasizes profound understanding and the development of higher-order thinking skills, creativity, collaboration, and communication (Otto et al., 2020).

However, the state of education in Indonesia indicates that higher-order thinking skills, including computational thinking, still need improvement. The results of the 2018 Program for International Student Assessment (PISA) survey noted that Indonesian students' science literacy and problem-solving skills remain below the international average, which indirectly reflects their low levels of systematic and analytical reasoning, including aspects underlying computational thinking such as problem decomposition and pattern recognition (Lestari & Annizar, 2020). Similar conditions have also been identified at the local level. Based on initial observations at Labuapi High School, 11th-grade students demonstrated difficulty in

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breaking down biological problems in a structured manner, identifying patterns in the digestive process, and formulating solutions using systematic scientific steps. This poses a unique challenge in learning biology, given that the digestive system curriculum requires students not only to understand concepts but also to analyze information logically and to design problem-solving strategies akin to algorithmic approaches (Wulandari et al., 2021).

The abstract and complex nature of biology content requires learning strategies that develop students' computational thinking skills. Students need to be trained to break down biological problems into simpler components, recognize patterns, and systematically formulate solution steps (Prandifa et al., 2023). However, based on observations at a public high school in Labuapi in 2025, the learning process remains dominated by conventional methods, such as lectures and question-and-answer sessions. The use of learning media and technology is also not yet optimal, so the development of students' computational thinking skills has not been maximized. Additionally, teachers' understanding of computational thinking concepts remains limited, so its implementation in the classroom is not yet optimal.

As an alternative, instructional innovations are needed to foster active student engagement while systematically developing computational thinking skills. However, in practice, teachers still face limitations in integrating computational thinking approaches into biology instruction, both in understanding the CT concept itself and in the lack of tools and instructional models that explicitly facilitate its four aspects (Wulandari et al., 2021). One relevant instructional model to address this is Problem-Based Learning (PBL), a student-centered model focused on solving real-world problems comprising five main phases: student orientation to the problem, student organization for learning, guided inquiry, development and presentation of work, and analysis and evaluation of the problem-solving process (Arends, 2012). Each PBL syntax directly stimulates aspects of computational thinking: the problem orientation stage trains decomposition, the investigation stage trains pattern recognition and abstraction, and the presentation of results stage trains algorithmic design by systematically constructing solutions.

This PBL model can be further integrated with Augmented Reality (AR) technology, which enables interactive visualization of three-dimensional objects in a real-world environment (Dewi et al., 2025). In the context of high school biology, AR serves as a medium that visualizes abstract processes, such as the mechanisms of digestion, through animations, thereby helping students build the mental representations necessary for the abstraction stage of computational thinking. Although previous studies have demonstrated the effectiveness of PBL in enhancing higher-order thinking skills in biology learning (Sholikhah et al., 2023) and the potential of AR in improving science concept understanding at the high school level (Citra et al., 2025), research specifically integrating AR-assisted PBL to develop computational thinking skills in high school digestive system material has not been widely conducted in Indonesia. The novelty of this study lies in testing the PBL–AR combination as a single treatment explicitly designed to measure the four CT

indicators, decomposition, pattern recognition, abstraction, and algorithm design, in the context of 11th-grade biology.

Based on the above discussion, there is a gap between the demands of 21st-century skills and actual teaching practices, particularly regarding the limited availability of instructional models that explicitly foster students' computational thinking in biology. Therefore, this study aims to analyze the effect of the Augmented Reality-assisted Problem-Based Learning model on the computational thinking skills of 11th-grade students at SMAN 1 Labuapi, as measured by four specific indicators: decomposition, pattern recognition, abstraction, and algorithm design related to the digestive system. The results of this study are expected to provide empirical contributions to the development of innovative biology learning and serve as a practical reference for teachers integrating CT into technology-based learning in the 21st century.

MATERIALS AND METHODS

Time and place

This study was conducted from November to December 2025 at State Senior High School 1 Labuapi, West Lombok Regency, West Nusa Tenggara, Indonesia, and comprised three learning sessions. The selection of State Senior High School 1 Labuapi as the research site was based on several considerations. First, this school is one of the public high schools in the West Lombok region that already has technology-supported learning facilities; however, their use to integrate innovative models, such as AR-assisted PBL in biology instruction, remains suboptimal. Second, based on initial observations, 11th-grade students at this school showed evidence of low computational thinking skills, as evidenced by difficulties in systematically analyzing biological problems and formulating solutions using the scientific method. The selection of the 11th grade specifically was based on the consideration that at this level, students have acquired the basic concepts of biology in 10th grade, making them better prepared to develop higher-order thinking skills, while simultaneously studying the digestive system, a topic with a high conceptual complexity that is relevant for integration with a computational thinking approach.

Research design

This study employed a quasi-experimental method using a non-equivalent control group design, which involves two groups, an experimental group and a control group, without randomization in group assignment. This design was chosen due to the field conditions, in which the 11th-grade level at SMAN 1 Labuapi consisted of only two classes; consequently, all available classes were designated as the experimental and control groups without randomization. The presence of a control group in this design provides a comparison that strengthens the study's internal validity, allowing changes in computational thinking skills to be more reliably attributed to the treatment administered rather than solely to external factors.

The experimental group was treated with a Problem-Based Learning (PBL) model supported by Augmented Reality (AR) over three sessions, while the control group received conventional instruction on the same material. A pretest was administered to both groups before the intervention to measure students' initial

computational thinking skills across four indicators: decomposition, pattern recognition, abstraction, and algorithm design. A posttest was administered after the entire treatment was completed to measure improvements in students' computational thinking skills across the same indicators. The success of the treatment was determined if there was a significant difference between the posttest results of the experimental group and the control group, which was analyzed using appropriate statistical tests. The research design can be described as follows:

Group	Pretest	Treatment	Posttest
Experiment	O ₁	X	O ₂
Control	O ₃	-	O ₄

Description:

O₁: Pretest in the treatment group

O₂: Post-test in the treatment group

X: Implementation of a problem-based learning model supported by augmented reality

O₃: Pretest in the control group

O₄: Post-test for the control group

This study was conducted to determine the effect of implementing an AR-assisted PBL model on students' computational thinking skills in biology instruction.

Research population and sample

The population of this study comprises all 11th-grade students at Labuapi State High School 1 during the 2025/2026 academic year. This study is a quasi-experimental study using a non-equivalent control group design, involving an experimental class and a control class. The sampling technique employed was saturation sampling, in which the entire population was used as the study sample. Thus, the research sample consists of two 11th-grade classes: one class as the experimental group and one class as the control group. The experimental group was treated with a Problem-Based Learning (PBL) model assisted by Augmented Reality (AR), while the control group received conventional instruction. Students' computational thinking skills were measured using an essay test. The research data were analyzed using an ANCOVA test to determine the effect of the treatment on students' computational thinking skills.

Research procedure

The population of this study comprises all 11th-grade students at Labuapi State High School 1 during the 2025/2026 academic year. This study is a quasi-experimental study using a non-equivalent control group design, involving an experimental class and a control class. The sampling technique employed was saturation sampling, in which the entire population was used as the study sample. Thus, the research sample consists of two 11th-grade classes: one class as the experimental group and one class as the control group. The experimental group was treated with a Problem-Based Learning (PBL) model assisted by Augmented Reality (AR), while the control group received conventional instruction. Students' computational thinking skills were measured using an essay test. The research data were analyzed using an ANCOVA test to determine the effect of the treatment on students' computational thinking skills.

Research data analysis

The data in this study were obtained from the pretest and posttest results of the students' computational thinking skills in both groups. The data were analyzed to determine the effect of implementing a Problem-Based Learning (PBL) model, aided by Augmented Reality (AR), on students' computational thinking skills, controlling for their initial abilities. The following are the steps taken in the data analysis:

Normality Test

Prior to hypothesis testing, a test of homogeneity of variances was conducted using Levene's test to ensure that the variances of the posttest data in the experimental and control groups were homogeneous. The decision criterion was as follows: if the significance level was > 0.05 , the variances were deemed homogeneous, and the assumptions of ANCOVA were met; whereas if the significance level was ≤ 0.05 , the variances were not homogeneous, and further adjustments to the analysis were warranted.

Hypothesis testing was conducted using analysis of covariance (ANCOVA) with pretest scores as a covariate. The use of the pretest as a covariate aimed to control for students' initial computational thinking abilities, so that posttest differences between the experimental and control groups could more accurately reflect the effect of the treatment administered, rather than differences in initial ability. The decision criteria based on significance levels are as follows: if $p < 0.05$, there is a significant effect of the AR-assisted PBL model on students' computational thinking skills; whereas if $p > 0.05$, there is no significant effect. In addition to significance levels, the magnitude of the treatment effect is measured using partial eta squared (η^2p). The interpretation of η^2p values follows these criteria: $\eta^2p = 0.01$ is considered a small effect, $\eta^2p = 0.06$ a moderate effect, and $\eta^2p = 0.14$ a large effect (Cohen, 1988). Reporting this effect size is important for providing a practical picture of how much the treatment contributes to improving students' computational thinking skills, rather than merely reporting statistical significance.

Hypothesis Testing

Hypothesis testing in this study was conducted using inferential statistics, specifically analysis of covariance (ANCOVA). The criteria for the ANCOVA test are as follows: if the probability or significance is < 0.05 ($p < 0.05$), it can be concluded that there is a partial effect of the independent variables on the dependent variable; however, if the significance is > 0.05 ($p > 0.05$), it can be concluded that there is no significant effect of each independent variable on the dependent variable.

RESULTS AND DISCUSSION

Result

Results of the Validity and Reliability Testing of the Instrument

Validity testing was conducted using the corrected item-total correlation technique by comparing the calculated r-values for each item against the table r-value ($df = 69$, table r-value = 0.233 at the 5% significance level). Test results for the 10 computational thinking ability test items with 71 respondents showed that all items were deemed valid, with calculated r-values ranging from 0.245

to 0.612, all above the table r-value. This range indicates good item quality consistency, from items with minimum to maximum discriminative power. Furthermore, the reliability test using Cronbach’s Alpha yielded a coefficient of 0.724. Based on Guilford’s criteria, this value falls into the high reliability category, so the instrument is deemed consistent and suitable for use in measuring students’ computational thinking skills.

Pretest and Posttest Results

The results of the analysis of students’ computational thinking skills revealed a clear difference between the experimental class and the control class. The average pretest score for the experimental class was 45.20 and for the control class was 46.80, indicating that the initial abilities of the two classes were relatively comparable. After the intervention, the average posttest score for the experimental class increased to 74.50, while the control class only reached 58.30. The difference in the patterns of improvement between the two classes can be seen in (Figure 1)

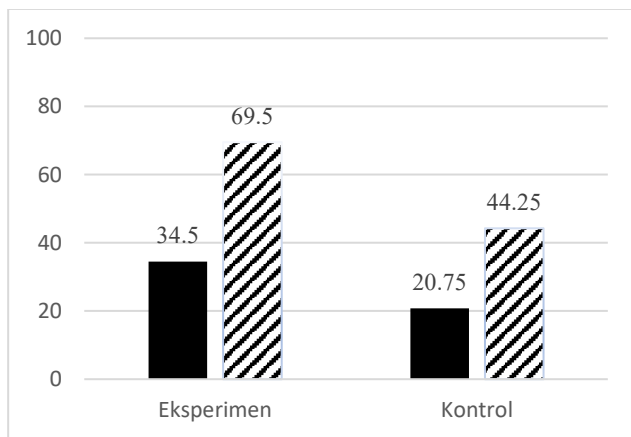


Figure 1. Average Scores for Computational Thinking

As shown in (Figure 1), there is a difference in the developmental patterns of computational thinking skills between the experimental class and the control class. The mean pretest score of the experimental class was slightly lower than that of the control class, indicating that the initial abilities of the two classes were relatively comparable. After the implementation of the learning strategy, the experimental class showed a significant improvement, reflected in the posttest mean score rising to the high category and surpassing that of the control class. The control class also experienced an improvement in computational thinking skills, but at a lower level. These findings confirm that the learning strategy applied to the experimental class was more effective in improving students’ computational thinking skills compared to the method used in the control class.

Results of the Data Normality Test

A normality test was conducted using the Shapiro-Wilk test ($\alpha = 0.05$) on the pretest and posttest data for both groups. The test results indicate that all data are normally distributed, as shown in Table 1.

Table 1. Summary of the Results of the Normality Test for Computational Thinking Data

Class	Data	Sig.	Sig.
Control	Pretest	.413	Normal
Control	Posttest	.573	Normal
Exsperiment	Pretest	.330	Normal
Exsperiment	Posttest	.330	Normal

Based on Table 1, all p-values are above 0.05, indicating that the assumption of normality is met for all groups and data types. Next, a test of homogeneity of variances was conducted using Levene’s test to satisfy the assumptions of ANCOVA. The results of Levene’s test showed a significance value > 0.05 , indicating that the posttest data variances in both groups are homogeneous. With the assumptions of normality and homogeneity met, the analysis proceeded using ANCOVA.

Results of the Hypothesis Test on Computational Thinking Skills

Hypothesis testing was conducted using ANCOVA, with pretest scores as a covariate to control for students’ initial ability. The results of the analysis are presented in Table 2.

Table 2. Summary of Computational Thinking Data Analysis Results

Sources of Variation	Sig.
Learning Model	.000

Table 2 shows a significance value of 0.000 ($p < 0.05$), so H_0 is rejected and H_1 is accepted, meaning that the AR-assisted PBL model has a significant effect on students’ computational thinking skills. The pretest scores, as covariates, play a crucial role in this analysis because they allow for a posttest comparison between the two groups after controlling for initial ability statistically. This reinforces the validity of the conclusion that posttest differences reflect the effect of the treatment, not differences in initial ability. The adjusted mean for the experimental class was 67.620, higher than that of the control class at 46.130, which strengthens the evidence that the treatment had a meaningful effect. Based on the partial eta-squared (η^2p) value, the magnitude of the treatment effect falls into the large category ($\eta^2p > 0.14$) according to Cohen’s (1988) criteria, indicating that the AR-assisted PBL model is not only statistically significant but also makes a substantial practical contribution to improving students’ computational thinking skills.

Discussion

The results of the study indicate that the implementation of an AR-assisted PBL model significantly improved the computational thinking skills of 11th-grade students at SMAN 1 Labuapi regarding the digestive system, with the corrected average score of the experimental class (67.620) being higher than that of the control class (46.130). This finding aligns with the research by Auliya et al. (2025), which specifically integrated PBL and AR to enhance computational thinking skills in science learning, and stands as one of the studies explicitly examining the combination of both. Unlike the study by Azizah et al. (2024), which used PBL supported by a smart

app creator, this study demonstrates that AR provides unique added value through three-dimensional visualization of the digestive process, which directly supports the formation of students' mental representations, particularly regarding the abstraction aspect of computational thinking. Thus, the novelty of this study lies in testing PBL–AR as a single intervention designed to explicitly develop the four CT indicators in the context of high school biology.

The improvement in computational thinking skills can be explained by the direct connection between the PBL framework and the four CT indicators in the digestive system curriculum. During the problem-orientation stage, students are presented with real-world problems such as digestive disorders (gastritis, malabsorption), which foster decomposition skills through the structured analysis of digestive organs and functions. In the guided inquiry stage, students identify similarities in the mechanisms of digestive enzymes across various substrates, which trains their pattern recognition skills. The development and presentation of results stage encourages students to simplify the digestive process into a flowchart from ingestion to defecation, reflecting their abstraction skills. Meanwhile, in the analysis and evaluation of solutions stage, students formulate systematic steps to solve digestive problems, representing algorithmic design skills (Yuntawati et al., 2021; Pratiwi & Akbar, 2022). Throughout these stages, AR plays an active role in visualizing the digestive process in three dimensions, thereby facilitating students' construction of the mental representations required for abstraction and pattern recognition, while simultaneously creating a learning environment that fosters greater cognitive engagement and active participation (Einsthendi et al., 2024; Sulhaliza et al., 2025).

Nevertheless, this study has several limitations that must be acknowledged. First, the sample size, which was limited to two classes in a single school, reduces the generalizability of the findings. Second, the non-equivalent control group design without randomization may leave confounding variables that are not fully controlled, even though a pretest was used as a covariate. Third, limited access to AR-enabled devices in the field may affect the consistency of students' learning experiences. These limitations need to be addressed in future research with a broader sample scope, a more rigorous experimental design, and the development of more accessible AR media.

CONCLUSION

There is an effect of problem-based learning supported by augmented reality on the computational thinking skills of 11th-grade students at SMAN 1 Labuapi. This is evidenced by the results of the hypothesis test, which indicate that the null hypothesis (H_0)—stating that there is no effect of problem-based learning supported by augmented reality on students' computational thinking skills—was rejected, while the alternative hypothesis (H_1) was accepted. This effect is supported by the corrected mean score for computational thinking skills in the experimental class of 67.620, which is higher than the corrected mean score of the control class of 46.130.

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AUTHOR'S CONTRIBUTION

The author is fully responsible for the entire research process and the preparation of the manuscript. All stages of the research, from conceptualization to the writing of the article, are carried out independently by the author.

Table of Author Contributions

Contribution Indicator	Author				
	1	2	3	4	5
Conceptualization	✓	✓	✓		
Literature Review	✓		✓	✓	
Research Design / Methodology		✓	✓	✓	
Instrument Development	✓	✓		✓	
Data Collection	✓				✓
Data Curation		✓	✓	✓	
Formal Analysis	✓	✓	✓		
Data Interpretation	✓		✓		
Writing – Original Draft	✓				
Writing – Review & Editing		✓	✓	✓	✓
Visualization / Tables	✓				
Supervision	✓	✓	✓	✓	✓

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