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Problem-based learning with baamboozle edugame: Enhancing critical thinking skills and learning interest

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Abstract

Background: Developing students' critical thinking skills and learning interest is essential in mathematics education, particularly in complex topics like discrete mathematics. Problem-Based Learning (PBL) models, integrated with educational technology such as the Baamboozle edugame, have the potential to address these educational challenges.
Aim: This study investigates the effect of the Problem-Based Learning (PBL) model assisted by the Baamboozle edugame on students' critical thinking skills and their learning interest.
Method: A quasi-experimental design was employed, involving an experimental group using the PBL model with Baamboozle and a control group following conventional teaching methods. Data were collected using posttest instruments to measure critical thinking skills and learning interest.
Results: The findings reveal significant differences in both critical thinking skills and learning interest between the experimental and control groups. The experimental group achieved an average posttest score of 84.28 in critical thinking skills compared to 53.43 in the control group. For learning interest, the experimental group scored 75.83, outperforming the control group's 70.13.
Conclusion: The study concludes that the PBL model integrated with the Baamboozle edugame effectively enhances students' critical thinking skills and learning interest in discrete mathematics. This approach demonstrates the potential of combining innovative learning models with educational technology to improve student outcomes.

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INTRODUCTION

In the 21st century, critical thinking and learning interest are increasingly recognized as essential competencies for academic success and lifelong learning. These skills empower students to analyze complex problems, generate innovative solutions, and maintain engagement in their educational pursuits (Aizikovitsh-Udi & Cheng, 2015). Their importance is particularly evident in mathematics education, where abstract and challenging topics, such as discrete mathematics, require deep understanding and analytical thinking (Suranchiyeva et al., 2023). Teaching strategies that foster critical thinking have been shown to significantly enhance higher-order thinking skills, which are critical for students' academic and personal development (Aizikovitsh-Udi & Cheng, 2015; Sachdeva & Eggen, 2021). Furthermore, structured pedagogical approaches in discrete mathematics not only strengthen problem-solving abilities but also improve engagement and comprehension of abstract concepts (Suranchiyeva et al., 2023). Integrating mathematical modeling into discrete mathematics provides practical applications that stimulate students' critical thinking and interest in learning (Greefrath et al., 2022). Additionally, discrete mathematics is recognized as a foundational discipline in fields like computer science, highlighting its global significance in preparing students for the challenges of an interconnected world (González et al., 2021). These findings underscore the

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need for innovative teaching strategies that not only enhance critical thinking and learning interest but also address the unique demands of mathematics education in the 21st century.

Given the growing importance of critical thinking and learning interest in mathematics education, especially in addressing abstract topics such as discrete mathematics, it becomes imperative to identify effective teaching strategies that can foster these competencies. Among various instructional approaches, Problem-Based Learning (PBL) has consistently been identified as one of the most effective methods (Mahendra & Sugiharni, 2022; Nguyễn, 2021; Saepuloh et al., 2021; Wenno et al., 2021). PBL centers on student-driven learning through real-world problems, encouraging higher-order thinking, active engagement, and deeper understanding (Pertiwi, 2022). Numerous studies have demonstrated its ability to enhance students' conceptual mastery, problem-solving abilities, motivation, and critical thinking (Hussin et al., 2018; Lisniandila et al., 2019; Syahfitri & Sulaiman, 2023). Furthermore, PBL has been shown to stimulate creativity by enabling students to approach complex problems with innovative solutions (Leasa et al., 2021; Wenno et al., 2021). Its effectiveness spans various disciplines, including mathematics, where its structured approach aligns well with the analytical demands of discrete mathematics (Choon et al., 2021; Nguyễn, 2021). Recent advancements also highlight the potential of integrating PBL with technological tools, such as simulations and online platforms, to further support critical thinking and problem-solving (Irawati & Sulisworo, 2023). These findings position PBL as a transformative instructional approach to meet the evolving demands of 21st-century education.

The integration of Problem-Based Learning (PBL) with game-based learning has emerged as a promising strategy to enhance learning outcomes across various disciplines. This combination capitalizes on PBL's emphasis on real-world problem-solving and critical thinking while leveraging the interactive, engaging, and motivating nature of game-based learning. Educational games, with their elements of competition, rewards, and immediate feedback, foster collaboration, critical dialogue, and sustained student interest through immersive experiences (Papadakis et al., 2021; Tokac et al., 2019). For instance, Adams et al. (2017) demonstrated that students who learned mathematics through educational games performed better, enjoyed the learning process more, and made fewer errors compared to those taught through traditional methods. Similarly, Papadakis et al. (2021) found that interactive gaming on touchscreen devices improved preschoolers' mathematical thinking by providing an engaging platform to explore abstract concepts, reducing anxiety and building foundational skills. These findings underscore the potential of combining PBL and game-based learning to address diverse learning needs through customizable and adaptable activities. By blending the structured approach of PBL with the dynamic elements of game-based learning, educators can create inclusive environments that enhance academic performance, foster positive attitudes toward learning, and better prepare students to tackle real-world challenges.

Building on this idea, Baamboozle stands out as a web-based educational game that offers a variety of interactive and engaging activities. It is designed as a quiz-like game that can be used in classrooms or online learning environments, played through projectors, smart boards, or other devices (Krisbiantoro, 2020; Sa'diyah et al., 2021). Baamboozle can be played in groups, featuring themes like occupations, animals, oceans, music, transportation, and more. Groups select a theme image to display questions on the screen, answer them collaboratively, and receive feedback with the correct answer. The game also includes power-up features, such as adding or subtracting points, doubling scores, and other dynamic mechanics to maintain student engagement and excitement. As illustrated in Figure 1, Baamboozle divides players into teams, allowing them to select visually appealing tiles that represent various themes, such as marine life. This interactive interface fosters collaboration and excitement in classroom activities, making it a versatile tool for enhancing engagement and learning interest.

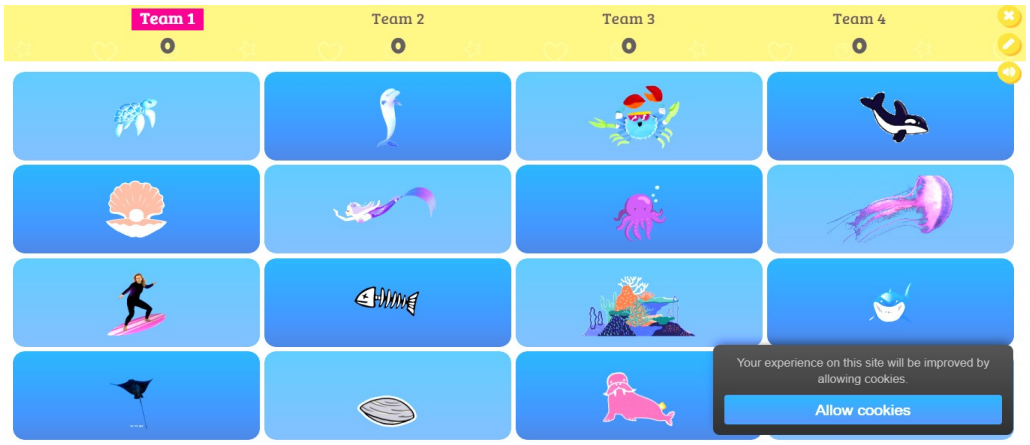

Figure 1. Interface of Baamboozle showing team-based gameplay with a marine life theme

Despite these advantages, the integration of game-based learning into PBL, especially in mathematics education, remains underexplored (Byun & Joung, 2018; Tokac et al., 2019). A meta-analysis by Tokac et al. (2019) revealed that out of more than 800 studies reviewed, only 24 directly compared game-based learning in mathematics with traditional methods, highlighting the scarcity of research in this area. Nonetheless, researchers argue that combining PBL and game-based learning can significantly increase students' interest and engagement, making it an innovative approach to address challenges in mathematics education (Fan et al., 2023). These findings underline the potential of integrating educational games, such as Baamboozle, within the PBL framework to create a more effective and enjoyable learning experience for students.

Building on this gap, several studies have highlighted the effectiveness of Problem-Based Learning (PBL) compared to conventional teaching methods (Arifin et al., 2022; Mashuri et al., 2019; Nisa' et al., 2023; Rusniati, 2023; Sholikhakh et al., 2019; Suparya et al., 2022). Additionally, PBL has been shown to enhance critical thinking skills and learning interest (Ardiwianti et al., 2022; Siregar et al., 2023). Game-based learning approaches also have a positive impact on students' interest in learning (Sinaga et al., 2023). Rifayanti et al. (2024) revealed that game-based approaches can improve critical thinking and problem-solving skills, particularly for upper elementary students. Similarly, Cicchino (2015) demonstrated the effectiveness of game-based learning in facilitating critical dialogue among students, while Nopiah et al. (2009) found that PBL approaches enhance the generic skills of engineering students in statistical courses. Abayeva et al. (2024) emphasized the importance of mathematics-based teaching in fostering critical thinking development at technical universities. Hsbollah & Hassan (2022) observed that integrating technology with active learning strategies creates meaningful educational experiences, while Escobar et al. (2022) discussed how gamification principles can enhance transversal competencies in higher education. Moreover, Novalinda et al. (2023) found that PBL approaches enhance the generic skills of engineering students in statistical courses. These findings emphasize the potential synergy between PBL and game-based learning in addressing educational challenges. However, the specific exploration of combining PBL with games like Baamboozle remains limited, particularly in mathematics education.

However, the use of educational games such as Baamboozle within the PBL model has not been thoroughly explored, particularly in terms of its impact on critical thinking skills and learning interest, especially in discrete mathematics contexts. Research that specifically integrates Baamboozle edugame into the PBL model to enhance students' critical thinking skills and learning interest in discrete mathematics remains scarce. Therefore, this study aims to address this gap by investigating the effectiveness of Baamboozle edugame as part of the PBL model in supporting critical thinking skills and learning interest in discrete mathematics.

METHOD

Research Design

This study employed a quasi-experimental research design, specifically a pretest-posttest with nonequivalent groups design. The quasi-experimental approach was chosen because participants were not randomly assigned to the experimental and control groups. The design involved two groups: the experimental group, which received Problem-Based Learning (PBL) assisted by the Baamboozle edugame, and the control group, which used conventional teaching methods. Both groups were tested on dependent variables using pretest and posttest measurements. The design is illustrated in Figure 2.

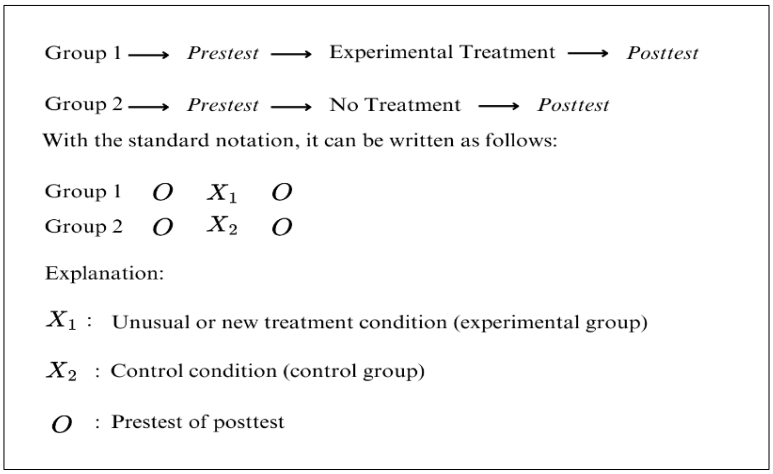

Figure 2. Research Design Notation

Participant

The population of this study consisted of 111 second-semester students enrolled in the Informatics Engineering Program at Universitas Ma'arif Nahdlatul Ulama (UMNU) Kebumen during the 2023–2024 academic year. The sample was selected by drawing lots from four parallel classes. Two classes were chosen: TI10B as the experimental group and TI10A as the control group. In the experimental group, mathematics was taught using PBL assisted by the Baamboozle edugame, while the control group used conventional teaching methods.

Instrument

The instruments used in this study included a critical thinking test and a learning interest questionnaire:

1. **Critical Thinking Test**: The test consisted of 5 essay questions covering the critical thinking skills of interpretation, analysis, evaluation, inference, explanation, and self-regulation (Facione, 2011)
2. **Learning Interest Questionnaire**: This questionnaire was developed based on indicators such as enjoyment, interest, attention, and engagement in learning mathematics (Febrianti et al., 2023; Friantini & Winata, 2019; Sholehah et al., 2018). It contained 20 items (12 positive and 8 negative statements) with a five-point Likert scale: Strongly Agree (5) to Strongly Disagree (1) for positive items and reverse scoring for negative items.

Data Analysis

The data analyzed in this study included scores from the critical thinking test and the learning interest questionnaire. The analysis process consisted of the following steps:

1. **Preliminary Analysis**

Before the main analysis, preliminary tests were conducted on the pretest data to ensure that the assumptions for multivariate analysis were met:

- **Normality Test**: To determine whether the data were normally distributed.
- **Homogeneity Test**: To ensure equal variances across groups.
- **Linearity Test**: To verify that the relationship between variables was linear.
- **Multicollinearity Test**: To confirm that the independent variables were not highly correlated.

2. Post-treatment Analysis

After the intervention, both the experimental and control groups completed the posttest. Posttest data were analyzed to evaluate the effect of the treatment on the dependent variables (critical thinking skills and learning interest).

3. Multivariate Analysis

Hypotheses were tested using Multivariate Analysis of Variance (MANOVA) with SPSS software. This method was chosen to compare the mean scores of the dependent variables across the two groups simultaneously.

- The independent variable was the teaching model (PBL assisted by Baamboozle vs. conventional methods).
- The dependent variables were **critical thinking skills** and **learning interest**.

4. Post Hoc Tests

If significant differences were found through MANOVA, post hoc tests were conducted to identify which specific groups or variables contributed to the differences.

By employing this systematic approach, the study aimed to determine the effectiveness of the intervention in enhancing students' critical thinking skills and learning interest while ensuring the robustness and validity of the results.

RESULTS AND DISCUSSION

Results

1. Descriptive Analysis

The results of the pretest and posttest for critical thinking skills and learning interest in the experimental and control groups are presented in Table 1 below:

Table 1. Descriptive Statistics of Critical Thinking Skills and Learning Interest

Groub	Variable	Pretest (Mean)	Posttest (Mean)	Improvement
Experimental	Critical Thinking	37.31	84.28	46.97
	Learning Interest	72.62	75.83	3.21
Control	Critical Thinking	33.47	53.43	19.96
	Learning Interest	68.00	70.13	2.13

Descriptive Interpretation:

- For critical thinking skills, the experimental group experienced a significantly higher improvement (46.97 points) compared to the control group (19.96 points). This indicates that the implementation of the PBL model assisted by the Baamboozle edugame is more effective in enhancing critical thinking skills.
- For learning interest, the experimental group also demonstrated a higher improvement (3.21 points) compared to the control group (2.13 points). Although the increase is more moderate compared to critical thinking skills, it still highlights the positive impact of integrating Baamboozle into learning.

To strengthen the analysis, the differences in pretest and posttest results for both variables are visualized in the following charts:

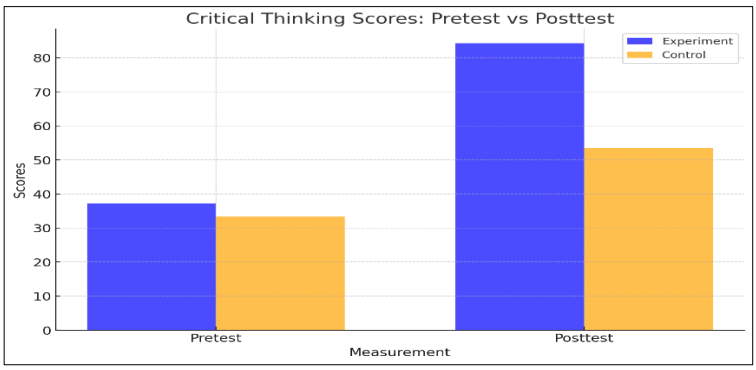

Figure 3. Critical Thinking Skills: Pretest vs. Posttest

This chart illustrates a significant improvement in the experimental group compared to the control group. The results emphasize that the PBL model assisted by Baamboozle has a greater effect on enhancing students' critical thinking skills.

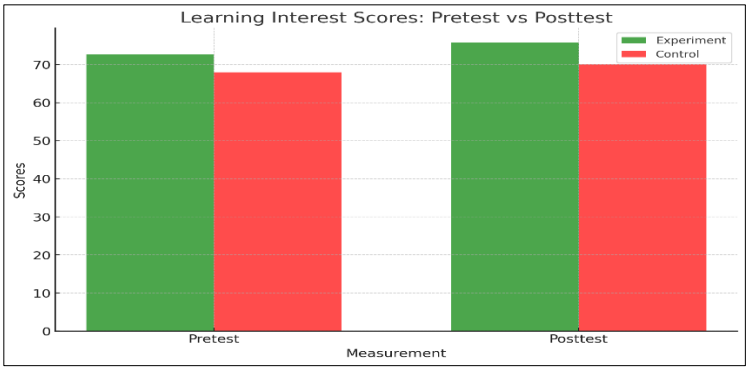

Figure 4. Learning Interest: Pretest vs. Posttest

This chart shows a more moderate improvement in learning interest, but the experimental group still exhibits a greater increase compared to the control group. This underscores that incorporating educational games into the learning process can effectively enhance students' interest in learning. The descriptive results and visual representation make it clear that the PBL model assisted by Baamboozle is more effective than conventional methods in improving students' critical thinking skills and learning interest.

2. Inferential Analysis

a. Normality Test

Pretest and posttest data on critical thinking skills and interest in learning were declared to be normally distributed based on the results of the Shapiro-Wilk test. Details of the test results are shown in Table 2.

Table 2. Shapiro-Wilk Normality Test Results

Groub	Variable	Pretest (Sig.)	Posttest (Sig.)	Conclusion
Experimental	Critical Thinking	0,266	0,117	Normal
	Learning Interest	0,851	0,574	Normal
Control	Critical Thinking	0,306	0,209	Normal
	Learning Interest	0,523	0,051	Normal

b. Covariance Matrix Homogeneity Test

The Box's M test results show a sig value. of 0.321 (>0.001), so the data is declared homogeneous.

c. MANOVA Test

MANOVA results showed significant differences between the experimental and control groups. Details are presented in Table 3.

Table 3. Result of MANOVA Test

Variable	F-value	Sig.	Conclusion
Critical Thinking	20,563	0,000	Significant difference
Learning Interest	8,132	0,004	Significant difference

d. Advanced Test (Post Hoc)

Further test results showed that the experimental group had a higher average value on both variables than the control group.

Discussion

This study highlights the significant effectiveness of integrating the Problem-Based Learning (PBL) model with the Baamboozle edugame in enhancing students' critical thinking skills and learning interest. By engaging students in real-world problems and complementing the process with interactive gaming elements, this approach successfully addresses both cognitive and motivational aspects of learning. The improvement in critical thinking skills, particularly in the experimental group, underscores the pivotal role of PBL in fostering higher-order cognitive processes (Mahendra & Sugiharni, 2022; Nguyễn, 2021). Baamboozle enriches this process by adding gamified features such as collaborative challenges and instant feedback, which enhance students' ability to analyze and evaluate complex problems (Adams et al., 2017). These features are integral in helping students develop self-regulation and reflection, key components of critical thinking as highlighted by Facione & Facione (2011). These findings underscore the potential of combining structured problem-solving approaches like PBL with engaging gamified tools such as Baamboozle to create a more holistic and effective educational strategy that addresses the diverse learning needs of students.

The motivational benefits of using Baamboozle are reflected in the moderate increase in learning interest within the experimental group. While the improvement in learning interest was not as pronounced as in critical thinking skills, it demonstrates the game's ability to create a dynamic and engaging learning environment (Sinaga et al., 2023). The competitive and thematic features of Baamboozle capture students' attention and make learning more enjoyable, which is particularly beneficial during challenging subjects like discrete mathematics (Escobar et al., 2022). Although the control group also showed a slight increase in learning interest, the difference highlights the added value of gamification in education. Nevertheless, the integration of Baamboozle demonstrates its potential as a motivational tool that complements the structured approach of PBL, making learning more appealing and relatable.

The combination of PBL and Baamboozle not only enhances learning outcomes but also addresses challenges often encountered in mathematics education. Discrete mathematics, known for its abstract concepts, can pose significant difficulties for students, leading to disengagement and frustration (Greefrath et al., 2022; Abayeva et al., 2024). Incorporating gamified elements into the learning process helps simplify complex topics and make them more accessible. Baamboozle's interactive nature allows students to engage with mathematical concepts practically and enjoyably, reducing anxiety and building confidence. Furthermore, the collaborative aspects of the game encourage peer interaction and collective problem-solving, fostering a supportive learning community (Novalinda et al., 2023). This synergy between PBL and Baamboozle not only transforms the learning experience in discrete mathematics but also fosters a more inclusive and engaging educational environment, empowering students to overcome challenges and achieve deeper understanding.

Implications

The findings of this study emphasize the importance of adopting innovative teaching strategies that combine structured problem-solving frameworks with engaging technological tools. This approach addresses both cognitive and emotional aspects of learning, making it particularly relevant in mathematics education. By leveraging gamified features, educators can create inclusive and interactive classrooms that support both critical thinking and learning interest. Furthermore, the alignment of PBL with gamification principles underscores the potential for this model to be applied in other STEM subjects, where complex and abstract concepts often challenge student engagement.

At an institutional level, these findings highlight the need for teacher training programs that focus on the integration of game-based learning tools within structured pedagogical models. Educational policymakers should also consider investing in technological infrastructure and resources to support such innovative approaches. This would enable broader implementation of gamified PBL models, preparing students to meet the demands of the 21st-century workforce.

Limitations and Suggestions

Despite its promising outcomes, this study has several limitations that warrant consideration and offer directions for future research. The relatively short duration of the intervention may have restricted the full potential of the PBL model with Baamboozle in influencing students' long-term learning outcomes. Extending the intervention period in future studies could provide a more comprehensive understanding of the sustained effects of this innovative teaching strategy. Additionally, the sample was limited to second-semester university students, a demographic that likely possesses a higher baseline of critical thinking skills and learning motivation compared to younger learners or those in less structured educational environments. Exploring this model across various educational levels, such as high school or elementary settings, could help assess its broader applicability. Moreover, the study focused solely on Baamboozle as the gamified learning tool, leaving an unexplored area regarding the comparative effectiveness of other tools such as Kahoot, Quizizz, or other game-based platforms. Future research could address this by evaluating the strengths and weaknesses of different gamified tools to determine their relative contributions to improving critical thinking and learning interest.

From a practical perspective, professional development programs are needed to equip educators with the skills to effectively integrate gamified tools like Baamboozle into the PBL framework. Institutions should also invest in the necessary technological infrastructure, such as smart boards and high-speed internet, to facilitate the seamless adoption of these innovative strategies in classrooms. Furthermore, policymakers are encouraged to incorporate gamified PBL models into national education curricula, particularly for STEM subjects, where critical thinking and engagement are vital. By addressing these limitations and building on the suggestions provided, future research and practice can contribute to refining and expanding the use of gamified PBL models in various educational contexts, ultimately enhancing both cognitive and motivational learning outcomes.

CONCLUSION

This study demonstrates the significant effectiveness of integrating the Problem-Based Learning (PBL) model with the Baamboozle edugame in enhancing students' critical thinking skills and learning interest in mathematics education. The findings reveal that the experimental group experienced substantial improvements in both critical thinking and learning interest compared to the control group, highlighting the potential of combining structured problem-solving frameworks with interactive and gamified learning tools. By engaging students in real-world problems and incorporating collaborative and dynamic gaming elements, this approach addresses both cognitive

and motivational aspects of learning. The integration of Baamboozle into PBL provides an engaging platform that enhances students' analytical abilities, fosters teamwork, and sustains interest in challenging subjects such as discrete mathematics. The results underscore the importance of adopting innovative instructional strategies that combine technological tools with active learning models to create a more inclusive and effective learning environment. Future studies should explore the application of this model across different educational levels and contexts, examine its long-term impacts, and investigate its scalability with other gamified tools. Ultimately, this research contributes to the growing body of evidence supporting gamified PBL as a transformative approach to modern education, equipping students with essential skills for the 21st century.

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AUTHOR CONTRIBUTIONS STATEMENT

Endang Wahyuningsih: Led the conceptualization of the research design and methodology, supervised the overall study implementation, and guided the analysis and interpretation of data. Endang also coordinated the manuscript preparation, ensured its coherence, and handled all correspondence related to the publication.
Fina Hanifa Hidayati: Conducted the data collection, prepared the initial drafts of the manuscript, and contributed to the development of the literature review and theoretical framework. Fina also ensured that the study's objectives were well-aligned with the educational context.
Ghufron Zaida Muflih: Conducted statistical analyses, validated the findings, and contributed to the discussion of results. Ghufron also reviewed and refined the methodology section to ensure methodological rigor and reliability.
Fersellia: Assisted in the development of research instruments, facilitated the implementation of the intervention using Baamboozle, and contributed to the visualization and interpretation of results. Fersellia also provided technical support throughout the study.

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