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When beekeepers meet mathematics: A project for learning numeracy

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ABSTRACT

Integrating environmental issues into mathematics learning is a strategic way to strengthen contextual numeracy. However, students' numeracy skills are often low and disconnected from real-world problems, such as the ecological role of honeybees. This study examines the effect of project-based learning (PjBL) with a honeybee conservation context on grade 7 students' numeracy skill and knowledge about bees. A quasi-experimental design involved 122 students in two classes. Numeracy skill was assessed in both groups, while bee knowledge was measured only in the PjBL group using a one-group pre-/post-test design. Data were collected using numeracy tests and a bee-knowledge questionnaire with reliability scores of 0.66 and 0.65. Results indicated that the PjBL group experienced significantly greater gains in numeracy skills with mean scores increasing from 4.36 to 9.99, compared to 3.98 to 7.25 in the control group. The normalized gain (N-gain) of the experimental group (0.48, moderate) was significantly higher than the control group (0.28, low) ($F = 16.304$, $p < 0.05$). A significant interaction was also found between the learning model and students' initial ability levels on students' numeracy skills improvement ($F = 2.238$, $p = 0.011$), indicating that PjBL with a bee conservation context was particularly effective in improving the numeracy skills of students with low to moderate prior abilities. Furthermore, students' knowledge about bees in the PjBL group improved significantly, with mean scores increases from 4.79 to 7.06 and an N-gain of 0.31 (moderate category). The findings indicate that integrating bee conservation projects into mathematics learning effectively enhances numeracy skills while fostering ecological awareness, supporting the implementation of sustainable development goal 15 (life on land).

Keywords: context of bee conservation, knowledge of bees, numeracy skills, project-based learning, SDG 15

INTRODUCTION

The sustainable development goals (SDGs), adopted by the United Nations (2015), aim to address critical challenges in the economic, social, and environmental spheres. The SDGs consist of 17 interrelated goals that cover important aspects such as poverty alleviation, climate change mitigation, and efforts to balance economic development, environmental sustainability, and social inclusion for human well-being (Ibisch et al., 2016; Mathy & Blanchard, 2016; Sachs, 2012; Smith & Olesen, 2010). Therefore, the SDGs serve as a crucial guideline for all parties to build a more just, sustainable, and responsible future for present and future generations. This view aligns with Kioumarsi et. al (2022), who emphasize that sustainable development requires the integration of environmental, social, and economic dimensions into educational practices to support long-term global resilience.

In Indonesia, the implementation of the SDGs is regulated by presidential regulation no. 59 of 2017, which provides a framework for integrating global development goals into national policies (Bappenas, 2018). One of the main focuses of this agenda is SDG 4: quality education, which emphasizes the importance of inclusive and equitable education and promoting opportunities for lifelong learning for all (UNESCO, 2017). In the context of SDG 4, literacy and numeracy are considered essential basic skills that students must possess from primary to secondary education (OECD, 2023).

Numeracy involves the ability or skill to understand, use, and apply mathematical concepts and procedures in a variety of real-life situations. It encompasses arithmetic, algebra, geometry, logical reasoning, and problem-solving skills in diverse contexts (Gaunt & Visnovska, 2024; Geiger et al., 2015). In addition to technical skills, numeracy skill also reflects an individual's capacity to critically assess quantitative information and make decisions based on

This study is derived from the thesis work of Sri Intan Lina completed under the supervision of Rahmah Johar and Anwar.

mathematical data (Fadel, 2008; Goos et al., 2014; OECD, 2012). Hartatik and Nafiah (2020) explain that numeracy skills also involves the ability to interpret numerical and graphical information to make accurate decisions, which contributes significantly to the well-being of individuals and society. Therefore, numeracy skills is not only related to mathematical skills but also involves a positive attitude towards the use and application of mathematics in everyday life (Goos et al., 2012; Jonas, 2018).

According to the 2023 Indonesian education report, based on the 2022 minimum competency assessment (AKM), numeracy skills is crucial both within and outside the school context. However, Indonesian students' numeracy skills levels remain low. The 2022 AKM results show that only 40.63% of junior high school students achieved minimum numeracy competency, a 3.79% increase from 36.84% in 2021 (Pusmendik-Kemendikbud, 2023). Furthermore, the 2022 PISA results show Indonesia ranked 70th out of 81 countries with an average score of 366, far below the global average of 575 (OECD, 2023).

Low levels of students' numeracy skills can be caused by several factors, including teacher-centered instruction (Rohmah et al., 2022), limited use of numeracy-based assignments (Iswara et al., 2022), and the dominance of procedural questions that do not involve reasoning (Kholifasari et al., 2020). The lack of real-world context also makes it difficult for students to connect mathematics material to everyday life (Rodríguez-Marín et al., 2020), resulting in an inability to understand or visualize information in contextual problems (Nasrullah et al., 2022). These challenges emphasize the importance of shifting towards more meaningful and context-based learning approaches to improve numeracy skills holistically.

One promising context for supporting numeracy skills learning is bee conservation. Integrating environmental themes into mathematics learning has been increasingly recognized as a contemporary pedagogical approach that enables students to bridge abstract mathematical concepts with concrete ecological issues. Such interdisciplinary integration supports contextual numeracy by helping learners apply quantitative reasoning to environmental challenges (Kioumarsi et al., 2022). Within this framework, bee conservation offers a rich and timely context. Previous research has shown that beekeeping activities provide a rich source of ecological and mathematical learning, effectively connecting students to sustainability issues (Maidiyah et al., 2023). This context is crucial because bees play a central role in crop pollination, which supports biodiversity and global food security (Rollings & Goulson, 2019; Wiseman et al., 2025; Wratten et al., 2012). Unfortunately, bee populations are declining due to climate change (Zattara & Aizen, 2020), habitat loss (Cameron et al., 2011), pesticide use (Jackson et al., 2022), and disease outbreaks (Potts et al., 2020), all of which threaten global ecosystems. Furthermore, bees contribute to the achievement of 15 of the 17 SDGs, particularly SDG 15 (life on land), which emphasizes biodiversity protection (Patel et al., 2021).

Despite this, the role of bees as a keystone species remains poorly understood by the public, including students. Inaccurate knowledge has led to an unfounded fear of bees, often stemming from misinformation or negative experiences such as stings (Burns et al., 2021; Larson et al., 2021; Leto et al., 2024). In many schools, the topic of bees is under-represented, resulting in students having limited knowledge of their ecological value. This leads to low awareness and concern for bee conservation (Lindemann-Matthies et al., 2021; Silva & Minor, 2017). In fact, ecological knowledge has been shown to be a key foundation for developing sustainable attitudes and behaviors (Wang & Zhang, 2021). Misinformation can perpetuate stigma and fear of certain species (Wignall et al., 2019), while accurate and context-based understanding can promote a stronger commitment to biodiversity conservation, including bees (Lindemann-Matthies et al., 2021; Silva & Minor, 2017). Therefore, education that introduces ecological themes in a contextual, evidence-based, and accessible way is crucial for building ecological understanding and environmental stewardship from an early age.

Given the low numeracy skills and limited ecological knowledge among students, there is a need for an instructional model that is not only cognitively engaging but also contextual, meaningful, and capable of fostering active student involvement. Unfortunately, mathematics instruction in many schools remains dominated by conventional, one-way teaching that relies heavily on lectures and procedural exercises detached from real-life contexts (Nurhikmayati, 2020). Getenet (2024) also emphasize that teacher-dominated classrooms result in passive learning and limit students' opportunities for collaborative and reflective engagement.

In this regard, implementing more active and participatory learning is crucial to overcoming the limitations of traditional methods. One promising model is project-based learning (PjBL). PjBL is an instructional approach that actively involves learners in investigating and responding to complex questions, problems, or challenges rooted in real-life scenarios (Bell, 2010; Krajcik & Blumenfeld, 2014). Through this model, students collaborate, conduct inquiry, and produce tangible artifacts that represent their learning outcomes (Pan et al., 2020; Thomas, 2000). PjBL has been shown to foster higher-order thinking skills, creativity, collaborative competencies, and a deeper conceptual grasp of mathematics (Almulla, 2020; Alyani & Ratmanida, 2021; Amin et al., 2022).

Furthermore, PjBL facilitates interdisciplinary integration particularly between mathematics and environmental issues through authentic, contextually meaningful projects (Genc, 2015; Rohm et al., 2021). Within the framework of bee conservation, this model allows students to explore data on bee populations, honey production, and environmental fluctuations, and to develop practical educational or conservation strategies. The convergence of PjBL with education for sustainable development (ESD) is particularly salient, as both pedagogies emphasize active engagement, collaboration, and real-world problem-solving (Lozano et al., 2022). Consequently, implementing PjBL in the context of bee conservation can meaningfully enhance students' numeracy skills while fostering ecological knowledge and a strong sense of environmental responsibility from an early age.

Numerous studies have demonstrated the effectiveness of PjBL in improving students' numeracy through diverse learning contexts. For instance, Syadzali et al. (2024) used the wetland ecosystem as a context, while Masrukha and Budiarto

(2021) integrated ethnomathematical values to strengthen numeracy understanding. Similarly, Sari et al. (2024) emphasized the importance of real-world contexts, such as nutrition-related issues linked to SDG 2 and SDG 3, in developing valid and meaningful numeracy tasks. These findings highlight that the success of PjBL is significantly influenced by the relevance and strength of the context employed.

Nevertheless, studies that specifically connect PjBL with the context of bee conservation remain very limited. In fact, bee conservation is closely related to SDG 15 and holds significant educational value in fostering students' ecological awareness. The absence of research that integrates this context within PjBL to enhance both students' numeracy skills and their ecological knowledge about bees represents an important gap that this study seeks to address particularly in supporting the achievement of SDG 15. Specifically, this research aimed to:

(1) analyze the improvement of students' numeracy skills through the implementation of the PjBL model with a bee conservation context compared to conventional teaching,

(2) examine the interaction between the PjBL model and students' initial ability levels (low, medium, high) in influencing the improvement of numeracy skills, and

(3) investigate the improvement of students' knowledge about bees in support of SDG 15 through the implementation of the PjBL model with a bee conservation context.

Research Questions

The study was guided by the following research questions:

1. Is the improvement in students' numeracy skills greater when they are taught using the PjBL model with a bee conservation context compared to those taught through conventional instruction?
2. Is there a significant interaction between the PjBL model with a bee conservation context and students' initial ability levels (low, medium, and high) on students' numeracy skills improvement?
3. Is there a significant improvement in students' knowledge about bees through the implementation of the PjBL model with a bee conservation context in support of SDG 15?

Hypotheses

For this study, the following null hypotheses were developed and put to the test at a 0.05 level of significance:

1. The improvement in students' numeracy skills taught using the PjBL model with a bee conservation context is significantly better than that of students taught using conventional model.
2. There is no a significant interaction between the PjBL model with a bee conservation context and students' initial ability levels (low, medium, and high) on students' numeracy skills improvement.
3. There is a significant improvement in students' knowledge about bees through the implementation of the PjBL model with a bee conservation context in support of SDG 15.

METHODOLOGY

This study employed a quasi-experimental design with a pre-/post-test control group design to examine the impact of the PjBL model within the context of bee conservation on students' numeracy skills. This design was chosen due to practical limitations in the field that made random assignment of participants impossible. Nevertheless, this design still allowed for a balanced comparison between the experimental and control groups through pre- and post-test measurements. Furthermore, to assess students' knowledge about bees, a pre-experimental design in the form of a one group pre-/post-test was used, involving only the experimental class receiving the PjBL intervention. This was done because bee-related ecological content was not included in the regular curriculum for the control class, and ethical considerations limited exposure to ecological material to only those directly involved in the project.

This study was conducted during the 2024/2025 academic year at a public junior high school located in Banda Aceh City, Indonesia. The research context was conducted in a real classroom environment, allowing for the implementation and observation of innovative teaching practices. The study population consisted of all grade 7 students, totaling 122 students from four classes. Using purposive sampling, two classes were selected as the study sample, with each class consisting of 61 students. These classes were selected based on the following criteria:

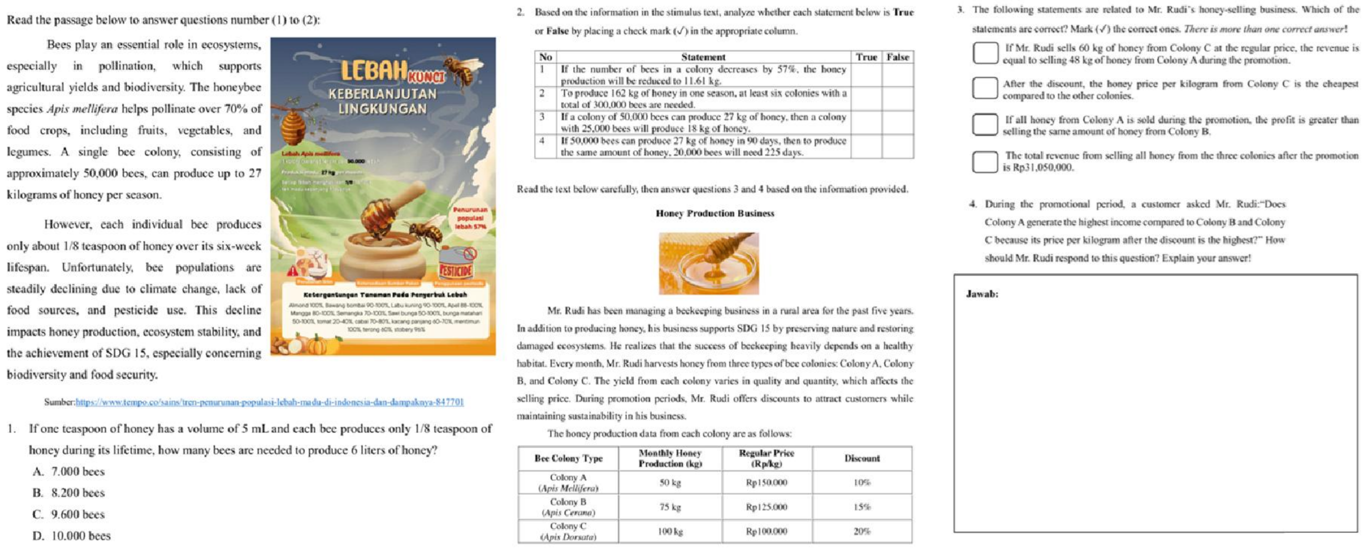
(1) both had relatively equivalent academic performance in mathematics based on the results of the previous semester,

(2) both were taught by the same teacher to ensure consistency of instruction, and

(3) both schedules allowed for uninterrupted implementation of the intervention during the predetermined period.

One class was assigned as the experimental group, receiving instruction through a PjBL model with a theme of bee conservation. Students in this group worked collaboratively on real-world projects, such as analyzing honey production data, examining the ecological role of bees, and creating awareness campaigns to support biodiversity and environmental sustainability. The other class served as the control group, receiving conventional instruction based on textbook exercises and teacher-led discussions without context-based learning or projects. Both groups completed pre- and post-tests to evaluate changes in their numeracy performance, while only the experimental group was assessed for their knowledge of bees before and after the intervention.

To minimize potential learning spillover, students in the PjBL group were scheduled in separate instructional sessions and were explicitly instructed not to discuss project-related tasks with students from other classes. The teacher also ensured that all project materials and worksheets remained inaccessible outside the designated PjBL sessions. These



Read the passage below to answer questions number (1) to (2):

Bees play an essential role in ecosystems, especially in pollination, which supports agricultural yields and biodiversity. The honeybee species *Apis mellifera* helps pollinate over 70% of food crops, including fruits, vegetables, and legumes. A single bee colony, consisting of approximately 50,000 bees, can produce up to 27 kilograms of honey per season.

However, each individual bee produces only about 1/8 teaspoon of honey over its six-week lifespan. Unfortunately, bee populations are steadily declining due to climate change, lack of food sources, and pesticide use. This decline impacts honey production, ecosystem stability, and the achievement of SDG 15, especially concerning biodiversity and food security.

Sumber: https://www.tempo.co/sains/tren-penurunan-populasi-lebah-madu-di-indonesia-dan-dampaknya-847701

1. If one teaspoon of honey has a volume of 5 mL and each bee produces only 1/8 teaspoon of honey during its lifetime, how many bees are needed to produce 6 liters of honey?
   A. 7.000 bees
   B. 8.200 bees
   C. 9.600 bees
   D. 10.000 bees

(a)

2. Based on the information in the stimulus text, analyze whether each statement below is **True** or **False** by placing a check mark (✓) in the appropriate column.

No	Statement	True	False
1	If the number of bees in a colony decreases by 57%, the honey production will be reduced to 11.61 kg.		
2	To produce 162 kg of honey in one season, at least six colonies with a total of 300,000 bees are needed.		
3	If a colony of 50,000 bees can produce 27 kg of honey, then a colony with 25,000 bees will produce 18 kg of honey.		
4	If 50,000 bees can produce 27 kg of honey in 90 days, then to produce the same amount of honey, 20,000 bees will need 225 days.		

Read the text below carefully, then answer questions 3 and 4 based on the information provided.

Honey Production Business

Mr. Rudi has been managing a beekeeping business in a rural area for the past five years. In addition to producing honey, his business supports SDG 15 by preserving nature and restoring damaged ecosystems. He realizes that the success of beekeeping heavily depends on a healthy habitat. Every month, Mr. Rudi harvests honey from three types of bee colonies: Colony A, Colony B, and Colony C. The yield from each colony varies in quality and quantity, which affects the selling price. During promotion periods, Mr. Rudi offers discounts to attract customers while maintaining sustainability in his business.

The honey production data from each colony are as follows:

Bee Colony Type	Monthly Honey Production (kg)	Regular Price (Rp/kg)	Discount
Colony A (*Apis Mellifera*)	50 kg	Rp150.000	10%
Colony B (*Apis Cerana*)	75 kg	Rp125.000	15%
Colony C (*Apis Dorsata*)	100 kg	Rp100.000	20%

(b)

3. The following statements are related to Mr. Rudi's honey-selling business. Which of the statements are correct? Mark (✓) the correct ones. *There is more than one correct answer!*
   - ☐ If Mr. Rudi sells 60 kg of honey from Colony C at the regular price, the revenue is equal to selling 48 kg of honey from Colony A during the promotion.
   - ☐ After the discount, the honey price per kilogram from Colony C is the cheapest compared to the other colonies.
   - ☐ If all honey from Colony A is sold during the promotion, the profit is greater than selling the same amount of honey from Colony B.
   - ☐ The total revenue from selling all honey from the three colonies after the promotion is Rp31,050,000.

4. During the promotional period, a customer asked Mr. Rudi: "Does Colony A generate the highest income compared to Colony B and Colony C because its price per kilogram after the discount is the highest?" How should Mr. Rudi respond to this question? Explain your answer!

Jawab:

(c)

Figure 1. Applied numeracy test items using a bee conservation context (Source: Authors' own elaboration)

measures helped substantially reduce the risk of cross-group contamination within the school environment.

The research instruments consisted of a numeracy test and a bee knowledge questionnaire. The numeracy test included four items designed according to the AKM framework, specifically in the algebra domain, with a focus on the ratio and proportion subdomain, and adapted to the numeracy indicators developed by Han et al. (2017). The bee knowledge questionnaire was developed based on the framework by Leto et al. (2024) and included 18 Likert-type items covering key ecological concepts related to bees and their role in supporting biodiversity. The questionnaire items were validated through expert judgment involving two biology educators and one environmental education specialist to ensure content accuracy and age-appropriateness. The items were also adapted from previously validated instruments (Leto et al., 2024; Silva & Minor, 2017), which strengthens the construct validity of the ecological knowledge measure. Reliability testing using Cronbach's Alpha yielded a coefficient of 0.66 for the numeracy test and 0.65 for the bee knowledge questionnaire, indicating acceptable internal consistency. Examples of numeracy items integrating the context of bee conservation are presented in **Figure 1**.

Figure 1 presents examples of applied numeracy test items developed using a bee conservation context. Item a assesses students' ability to extract quantitative information from a contextual reading passage, item b focuses on data interpretation and analytical reasoning, and item c evaluates decision-making skills related to honey production and pricing. Data analysis was performed using SPSS version 22. Pre- and post-test scores were first converted into interval scale data using the successive interval method. To ensure that the parametric tests used were appropriate, a normality test was conducted using the Kolmogorov-Smirnov test, while homogeneity of variance was tested using the Levene test. Improvements in numeracy skills and knowledge about bees were measured using the normalized gain (N-gain) formula developed by Hake (2002). Hypothesis testing was conducted using one-way ANOVA to assess the effect of the learning model, and two-way ANOVA to test the interaction between the learning model and students' initial ability levels. All tests were conducted at a significance level of 0.05. In addition, to analyze the improvement in students' knowledge about bees in the experimental group, a paired sample t-test was used.

Table 1. Descriptive statistics of students' numeracy skills

Score	Experimental			Control		
	N	M	SD	N	M	SD
Pre-test	61	4.360	1.533	61	3.982	1.891
Post-test	61	9.996	2.878	61	7.252	2.072
N-gain	61	0.480	0.196	61	0.280	0.155

Note. M: Mean & SD: Standard deviation

RESULT

This study analyzed data from students' numeracy tests and their knowledge about bees, collected from two groups: an experimental group and a control group. The analysis focused on pre-test, post-test, and N-gain scores to evaluate improvements in students' numeracy skills in both groups. Meanwhile, the analysis of students' knowledge about bees was only conducted in the experimental group, using pre- and post-test data, as this intervention was not applied to the control group.

Research question 1. *Is the improvement in students' numeracy skills greater when they are taught using the PjBL model with a bee conservation context compared to those taught through conventional instruction?*

To answer this question, the pre- and post-test results of the numeracy scores of the experimental group (PjBL) and the control group (conventional teaching) were analyzed, as shown in **Table 1**. The experimental group showed an increase in the average score from 4.36 to 9.99, while the control group increased from 3.98 to 7.25. These results indicate that both groups experienced improvement, but the experimental group showed a greater increase. To further evaluate the magnitude of the improvement, the N-gain was calculated. The

Table 2. One-way ANOVA results for numeracy N-gain

N-gain	SS	df	MS	F	Sig.
Between groups	0.535	2	0.535	16.304	0.000
Within groups	3.941	120	0.033		
Total	4.476	121			

Note. SS: Sum of squares & MS: Mean square

Table 3. N-gain descriptive statistics based on students' initial ability levels

Initial ability	PjBL			Conventional		
	N	$M_{N\text{-gain}}$	SD	N	$M_{N\text{-gain}}$	SD
High	10	6.60	0.699	6	7.00	1.412
Medium	42	4.24	0.906	48	3.92	0.816
Low	9	2.33	1.323	7	1.00	1.907

Note. M: Mean & SD: Standard deviation

experimental group obtained an average N-gain score of 0.48, which is categorized as moderate, while the control group obtained an average N-gain score of 0.28, which is categorized as low. These findings indicate that the PjBL model has a stronger impact on improving students' numeracy skills compared to the conventional model.

Before conducting the hypothesis test, the assumptions of normality and homogeneity were tested first. The Kolmogorov-Smirnov test confirmed that both the pre-test and N-gain scores were normally distributed ($p > 0.05$), which met the assumption of normality. The Levene test showed homogeneity of variance with $p = 0.728$ for the pre-test and $p = 0.620$ for the N-gain scores, which met the assumption of equality of variance ($p > 0.05$). Thus, the data met the requirements for parametric testing using ANOVA.

Hypothesis 1. *The improvement in students' numeracy skills taught using the PjBL model with a bee conservation context is significantly better than that of students taught using conventional model.*

As shown in **Table 2**, the results of the one-way ANOVA analysis produced an F value of 16.304 with a p-value of 0.000. Since $p < 0.05$, the null hypothesis was rejected, indicating a statistically significant difference between the two groups. Therefore, it can be concluded that students who received instruction through the PjBL model with a bee conservation context showed a greater and significant increase in numeracy skills compared to students who received conventional instruction.

Research question 2. *Is there a significant interaction between the PjBL model with a bee conservation context and students' initial ability levels (low, medium, and high) on students' numeracy skills improvement?*

To answer this question, students were grouped into three initial ability levels high, medium, and low based on their pre-test scores. **Table 3** presents descriptive statistics for N-gain based on the learning model and students' initial ability levels.

Table 3 showed that in the experimental group, students with medium and low initial abilities achieved higher N-gain scores than those with high initial abilities. In contrast, in the control group, students with high initial abilities showed the greatest improvement.

Hypothesis 2. *There is no a significant interaction between the PjBL model with a bee conservation context and students' initial ability levels (low, medium, and high) on students' numeracy skills improvement.*

Table 4. Two-way ANOVA results for numeracy N-gain (test of between-subject effects)

Source	TSS	df	MS	F	Sig.
Corrected model	210.708[a]	5	42.142	31.808	0.000
Intercept	1,113.457	1	1,113.457	840.423	0.000
Learning model	2.785	1	2.785	2.102	0.150
Initial ability level	202.653	2	101.327	76.480	0.000
Learning model*initial ability level	5.929	2	2.965	2.238	0.011
Error	153.686	116	1.325		
Total	2,430.000	122			
Corrected total	364.393	121			

Note. TSS: Type III sum of square & MS: Mean square

Table 5. Pre- and post-test scores of students' knowledge about bees (PjBL group)

Test type	PjBL group		
	N	M	SD
Pre-test	61	4.788	4.231
Post-test	61	7.059	5.702

Note. M: Mean & SD: Standard deviation

The results of the two-way ANOVA analysis shown in **Table 4** yielded an F value of 2.238 and a significance value of $p = 0.011$ for the interaction between the learning model and students' initial ability levels. Since $p < 0.05$, the null hypothesis is rejected, indicating there is a significant interaction between the PjBL model with a bee conservation context and students' initial ability levels (low, medium, and high) on students' numeracy skills improvement. This indicates that the level of improvement in numeracy skills differs depending on the combination of the learning model and students' initial academic abilities.

Research question 3. *Is there a significant improvement in students' knowledge about bees through the implementation of the PjBL model with a bee conservation context in support of SDG 15?*

To examine this, students in the experimental group were given a pre- and post-test questionnaire measuring their knowledge of bees. **Table 5** shows an increase in the mean score from 4.79 on the pre-test to 7.06 on the post-test. The calculated N-gain was 0.31, which falls under the moderate category (Hake, 2002).

Before conducting the hypothesis testing, a normality check was carried out using the Kolmogorov-Smirnov test, which showed that both the pre-test and post-test scores were normally distributed ($p > 0.05$).

Hypothesis 3. *There is a significant improvement in students' knowledge about bees through the implementation of the PjBL model with a bee conservation context in support of SDG 15.*

To examine the significance of the improvement in students' knowledge about bees, a paired sample t-test was conducted. The results showed that the mean post-test score was higher than the pre-test score, with a difference of 2.27 points. The t-value was -23.532, with degrees of freedom (df) = 60 and a significance value of $p = 0.000$ ($p < 0.05$), indicating

Table 6. Percentage gain in students' bee knowledge

Statement	Pre-test (%)	Post-test (%)	Improvement (%)
(P1) Honeybees bite.	52.46%	69.86%	17.40%
(P2) Honeybees eat pollen.	50.16%	61.39%	11.23%
(P3) Honeybees eat fruit.	57.83%	64.67%	6.84%
(P4) Honeybees sting to suck blood.	56.95%	64.67%	7.72%
(P5) Honeybees can use nectar or hunt other living creatures for food.	54.20%	56.95%	2.75%
(P6) Honeybees sting to defend themselves.	56.95%	64.67%	7.72%
(P7) Honeybees enjoy stinging.	50.16%	56.95%	6.79%
(P8) Honeybees mainly sting humans.	56.95%	64.67%	7.72%
(P9) People are frequently stung by honeybees.	55.26%	61.39%	6.13%
(P10) During a picnic, honeybees approach food to eat it.	59.86%	66.95%	7.09%
(P11) Having fewer honeybees in the world would benefit farming.	63.48%	76.95%	13.47%
(P12) Pollution contributes to the decline of honeybee populations.	61.39%	76.95%	15.56%
(P13) Honeybees function as pollinators in our ecosystem.	55.26%	79.86%	24.60%
(P14) The balance of our ecosystem would collapse without honeybees.	56.95%	79.86%	22.91%
(P15) A decrease in bee populations would not affect the ecosystem.	50.16%	73.78%	23.62%
(P16) Habitat loss is a major cause of the honeybee population decline.	62.30%	69.86%	7.56%
(P17) A drop in honeybee numbers will lead to greater biodiversity in our ecosystem.	44.53%	76.95%	32.42%
(P18) The uncontrolled use of pesticides is responsible for the bee population decline.	44.53%	73.78%	29.25%

that the improvement was statistically significant. These findings suggest that students' knowledge about bees increased after participating in the PjBL model using a bee conservation context.

In addition to inferential statistical analysis using the paired sample t-test, descriptive analysis of each questionnaire item also revealed a positive trend in students' knowledge of bees. **Table 6** presents the percentage of correct responses for each item before and after the implementation of the PjBL model in the context of bee conservation.

Based on **Table 6**, all statements in the questionnaire showed an increase in the percentage of correct responses in the post-test compared to the pre-test. The most significant improvements were observed in statements related to the ecological role of honeybees, such as "honeybees function as pollinators in our ecosystem," which increased by 24.60%, and "a decline in honeybee populations will lead to greater biodiversity in our ecosystem," which rose by 32.42%. These findings indicate that the implementation of the PjBL model not only enhanced students' factual understanding but also fostered a greater sense of ecological awareness.

DISCUSSION

The results of this study indicate that the PjBL model with a bee conservation context significantly improves students' numeracy skills compared to conventional learning. This improvement is evident not only from higher post-test scores but also from the N-gain values that fall into the moderate to high category. This finding is consistent with the research of Pratama and Yelken (2024) who stated that PjBL can improve mathematical literacy through learning activities that actively engage students. Likewise, Isamer et al. (2023) explained that PjBL activities train students to think critically and understand numeracy concepts in a more applicable way. Mursid et al. (2021) and Setiyani et al. (2024) also noted that PjBL helps students connect mathematical concepts to real-life situations, making the material easier to understand and remember.

Although the results demonstrated a significant improvement in students' bee-related knowledge, the one-group pre-/post-test design inherently limits the causal inference. External variables such as teacher influence, prior exposure, or test familiarity could partially contribute to the observed gains. However, the use of standardized procedures, consistent instructional time, and controlled learning materials helped reduce these threats to internal validity.

The PjBL model also provides opportunities for students to engage in active learning, collaborate, and construct their own understanding. Serin (2019) highlighted that this model supports the development of critical thinking and problem-solving skills in real-life contexts. Fisher et al. (2021) found that students who learned through projects demonstrated stronger mathematical problem-solving abilities. Furthermore, PjBL has been shown to foster positive attitudes toward mathematics (Alenezi, 2020; Cai et al., 2023).

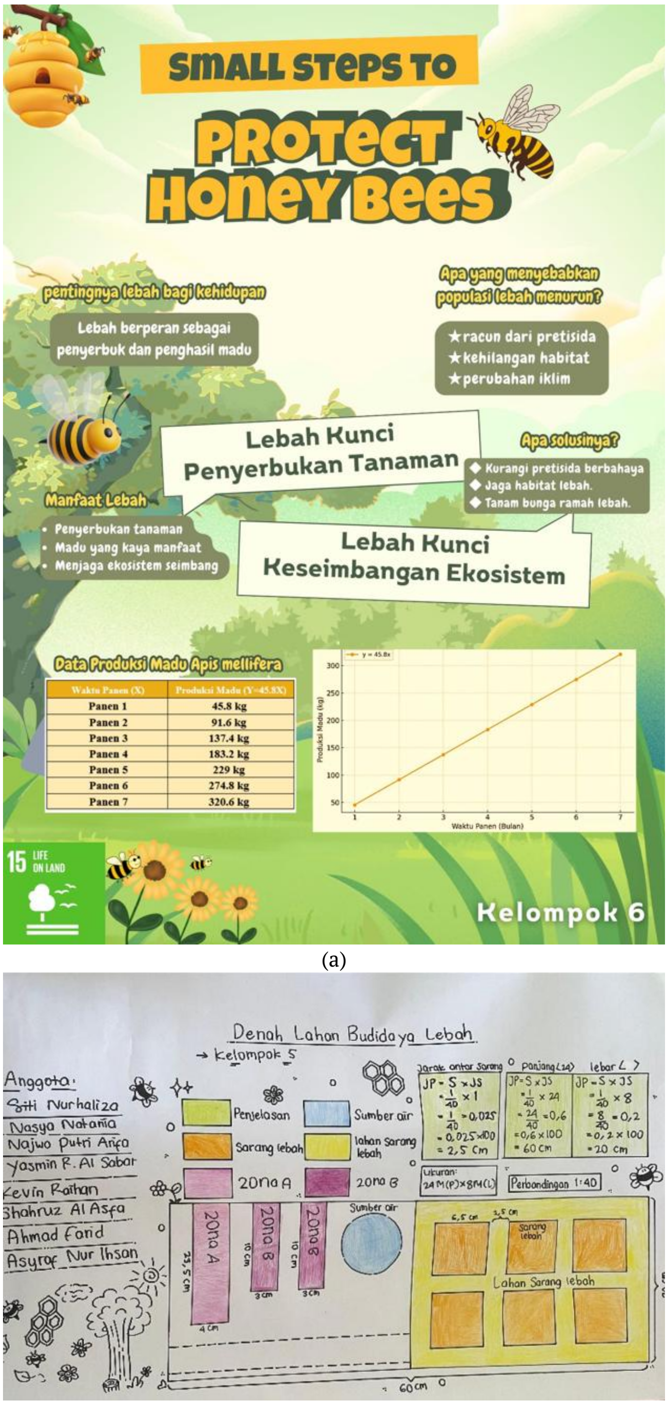
Figure 2 describes two main student projects in the PjBL model with the context of bee conservation:

(1) creating an educational poster entitled "small steps to protect bees" and

(2) designing a layout for a beekeeping area.

This poster project encourages students to integrate ecological data with scientific information about the role of bees in the ecosystem. Through visual representations such as graphs and tables of honey production, students develop numeracy skills including data interpretation, pattern recognition, and the ability to critically relate quantitative information to environmental issues.

Meanwhile, the beekeeping layout project required students to apply concepts such as scale, measurement, comparison, and proportion to design efficient beekeeping zones. This activity fostered spatial numeracy and contextual problem-solving skills, such as estimating land requirements and calculating colony distribution by zone. Both projects demonstrate that PjBL can offer authentic, applicable, and meaningful numeracy learning experiences while simultaneously building students' ecological awareness.



(a)

(b)

Figure 2. Students' project outputs: (a) educational poster and (b) beekeeping area layout (Source: Field study)

This research shows that the PjBL model, when applied in the context of bee conservation, has a significantly greater impact on students with low to moderate prior abilities. Beyond statistical significance, the 2.27-point increase represents a moderate practical improvement in students' ecological knowledge. Based on the effect size (Cohen's d), the gain can be interpreted as educationally meaningful, indicating that students not only remembered factual information but also demonstrated a deeper conceptual understanding of bees and their ecological roles.

As noted by Yusri et al. (2024), PjBL facilitates differentiated learning through collaborative and context-based tasks, enabling students of varying ability levels to engage meaningfully. Supporting this, Pradanti and Muqtada (2023) and Hossein-Mohand et al. (2021) highlight how real-life, hands-on learning experiences enable students to more effectively internalize abstract mathematical concepts.

In addition to its impact on numeracy skill, PjBL also significantly increased students' ecological awareness. This was evident in the increase in students' knowledge scores about bees in the post-test. Each questionnaire item showed improvement, with the most significant increase seen in statements related to the ecological function of bees, such as the statement "bees play a role as pollinators in our ecosystem" which increased by 24.60%, while the statement "the decline in the bee population will increase biodiversity in our ecosystem" increased by 32.42%. These findings indicate that contextual learning can build students' awareness of ecological issues, which are often overlooked in conventional teaching.

The use of bee conservation as a thematic context allows students to directly connect mathematical reasoning to pressing environmental issues. This supports the findings of Himmi et al. (2025), who stated that incorporating environmental projects into learning deepens both ecological literacy and mathematical understanding. Nityasanti et al. (2025) also confirmed that environmental-based projects are effective in promoting awareness of conservation issues while enhancing applied mathematical thinking.

Furthermore, PjBL in this context aligns closely with the SDGs, particularly SDG 15: life on land. Engaging in real-world projects allows students to directly explore environmental challenges and propose solutions, fostering the development of 21st century skills such as critical thinking, data literacy, and social responsibility (Camacho et al., 2023; Lozano et al., 2022; Sayer et al., 2019). Ho et al. (2022) found that engaging, context-based learning activities significantly increased students' motivation to engage with environmental content, while Fuertes et al. (2019) emphasized that a project-based approach fosters teamwork and a sense of social responsibility. Furthermore, Alenezi (2023) noted that PjBL enhances students' mathematical competence in solving digital and real-world problems.

The outcomes of this study provide valuable insights for future curriculum development. Integrating environmental contexts such as bee conservation into mathematics learning can strengthen numeracy skill while fostering ecological literacy and sustainability awareness. PjBL offers a pedagogical model that aligns well with competency-based curricula and ESD frameworks, supporting SDG 4 and SDG 15 by promoting relevant, context-based learning experiences. Curriculum designers may consider incorporating structured projects that blend mathematical problem-solving with environmental themes to encourage deeper engagement and interdisciplinary understanding.

Overall, PjBL in the context of bee conservation not only improves students' numeracy skills and their knowledge about bees but also fosters environmental awareness and equips them with essential skills to support sustainable development.

CONCLUSION

This study demonstrates that PjBL integrated with a bee conservation context represents a feasible and effective instructional approach for improving students' numeracy skills compared to conventional teaching. The main findings indicate that students who participated in PjBL achieved greater improvements in numeracy performance, with particularly strong gains observed among students with low to moderate prior ability levels. This suggests that PjBL supports inclusive and differentiated mathematics instruction in heterogeneous classrooms.

In addition to enhancing numeracy skills, the implementation of PjBL resulted in significant improvements in students' knowledge about bees, as reflected in higher post-test scores in the experimental group. These findings indicate that contextual, project-based mathematics learning can simultaneously strengthen mathematical understanding and foster ecological awareness, particularly regarding the role of bees in maintaining biodiversity and sustainable ecosystems, in alignment with 15 (life on land).

Although this study is subject to certain limitations, including the use of secondary data and the procedural structure of learning tasks, the results highlight the practical applicability of PjBL in school settings. Future research should focus on developing more inquiry-oriented and adaptive project designs to further enhance conceptual understanding and strengthen the integration of mathematics education with environmental sustainability.

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