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The Impact of Project Based Learning with Aquascapes on Metacognitive Skills and Learning Outcomes in Ecosystem Lesson

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Abstract: This study aims to determine the effect of the Project-Based Learning (PjBL) model based on aquascape media on students' metacognitive abilities and learning outcomes in ecosystem material. The research used a Pretest-Posttest Control Group experimental design, consisting of control and experimental classes. The population of the study included 241 tenth-grade students at SMAN 1 Idi Rayeuk, with a sample of 68 students determined through random sampling techniques. Data on metacognitive abilities were collected using a metacognitive state inventory, while learning outcomes were measured using written tests. Data analysis employed the Independent-Sample T test to analyze the impact of the PjBL model based on aquascape media on metacognitive abilities and learning outcomes. The results showed that the PjBL model had a significant effect on metacognitive abilities with a p-value of 0.030 ($p < 0.05$), as well as a significant effect on learning outcomes with a p-value of 0.000 ($p < 0.05$). In conclusion, the PjBL model based on aquascape media has a positive effect on enhancing students' metacognitive abilities and learning outcomes in ecosystem material.

Keywords: Aquascape; Learning outcomes; Metacognitive; Project based learning

Introduction

Recently, there has been a significant change in the Indonesian education system with the transition from the 2013 Curriculum to the Kurikulum Merdeka, which was introduced after the COVID-19 pandemic (Masaguni et al., 2023; Susanti et al., 2022). One of the key demands of the Kurikulum Merdeka is the development of metacognitive skills and higher-order thinking activities, which are essential potentials that need to be fostered in students (Fitriyani et al., 2022; Gao et al., 2022; Suratno, 2010).

Students with high metacognitive awareness will find the learning process easier because they can apply the knowledge, they acquire to solve problems they face. Metacognition is crucial in the learning process because it has a direct positive relationship with academic achievement, meaning the higher the metacognitive awareness, the better the learning outcomes (H. W. Kim et al., 2021; Mills et al., 2003; Nafiâah et al., 2022; Nuryana et al., 2012).

Despite its importance, there are still gaps in the implementation of metacognitive skills during the learning process, particularly in science subjects like biology (Puti et al., 2024). Recent research by Chalsum et al. (2023), Suprapto et al. (2022), Veenman et al. (2006), and Yanti et al. (2023) reveals that many teachers still struggle to integrate the development of metacognitive skills into daily learning. Meanwhile, Yanti et al. (2023), and Zohar et al. (2013) found that although much

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research has been conducted on metacognition in science education, there remains a need to develop effective learning strategies to enhance students' metacognitive abilities while meeting existing curriculum demands.

One of the main challenges in science education is the limited variety of teaching methods and the infrequent use of practical media. According to Sjøberg et al. (2019), science education is often too theoretical, making it difficult for students to connect with the subject (Azmi et al., 2023; Dewi et al., 2024). Certain biology topics, such as ecosystems and biodiversity, could be taught more effectively through real-life examples in the surrounding environment. Dori et al. (2018) and Yalçin et al. (2009) also highlight that a lack of hands-on and project-based learning hinders students' conceptual understanding.

To address this, innovative approaches like Project-Based Learning (PjBL) can be applied. PjBL encourages students to actively engage in real-life projects, enhancing skills such as critical thinking, problem-solving, and collaboration. Research by Kim et al. (2022) and Chen et al. (2019) supports the effectiveness of PjBL in boosting motivation, conceptual understanding, and metacognitive skills in science education (Rahmatan et al., 2022).

In biology, Hmelo-Silver et al. (2018), and Sarjani et al. (2023) demonstrated that integrating technology into PjBL helps students grasp complex ecosystem concepts. While PjBL has proven effective in various fields, its use with aquascape media to improve metacognitive skills has not been widely explored.

This study aims to fill that gap by examining the effectiveness of the PjBL model using aquascapes to enhance students' metacognitive skills and learning outcomes. Aquascapes, as miniature ecosystems, offer a real-world context for understanding ecosystem interactions, providing an innovative solution for improving students' learning experiences and outcomes.

Method

The research method used was experimental with an Experimental Design, namely a type of research consisting of a control class and an experimental class. The experimental group was given treatment by applying the Project-based learning model with aquascapes media while the control group used conventional methods. Pretest-Posttest Control Groups Design in this study can be seen in Table 1.

The research took place at SMA Negeri 1 Idi Rayeuk from February to June 2023 during the Even Semester of the 2022/2023 Academic Year, focusing on class X. The study's population encompassed 241 students from 8 class X sections of SMAN 1 Idi Rayeuk.

Table 1. Research Design

Class	Pretest	Treatment	Posttest
E	O_1	X	O_2
C	O_3		O_4

Description:
E : Experiment
K : Control
O_1 : Pretest score (before the application of project-based learning with aquascapes media)
O_2 : Posttest score (before the application of project-based learning assisted with aquascapes media)
O_3 : Pretest score (before the application of project-based learning)
O_4 : Posttest score (before the application of project-based learning)
X : Treatment

Table 2. Research Population

Class	Average Students Initial Score	N
X-IPAS-1	83	32
X-IPAS-2	83	36
X-IPAS-3	82	30
X-IPAS-4	83	29
X-IPAS-5	85	30
X-IPAS-6	82	27
X-IPAS-7	80	30
X-IPAS-8	83	27
Total number of students		241

The sample was taken using the random sampling technique, as this method allows for the random selection of samples from the population without considering the existing strata. This method was chosen because all 10th-grade classes have relatively similar initial abilities, allowing random sampling to give each member of the population an equal chance of being selected as a sample, ensuring more representative research results. The selected sample consists of two classes: X Science 1 and X Science 2.

Table 3. Research Sample

Class	Average Students Initial Score		N
Control	X-IPAS-2	83	36
Experiment	X-IPAS-1	83	32
Total number of students			68

There are two instruments used in the study: one for measuring students' metacognitive abilities and another for assessing their learning outcomes. The first instrument is used to measure students' metacognitive abilities, adopted and modified from the Metacognitive Awareness Inventory (MAI) developed by Schraw et al. (1994). This instrument focuses on the regulation of cognition, including planning (seven items), information management strategies (ten items), comprehension monitoring (seven items), debugging strategies (five items), and evaluation (six items). This inventory is considered suitable for adult learners (Panaaoura et al., 2003). The inventory used in the study consists of 35 questions with five alternative response options: strongly agree, agree, undecided, disagree, and strongly disagree.

The second instrument used in this study is a written examination. Written tests are administered to assess students' learning outcomes after they have participated in learning activities. This assessment includes objective tests in the form of pretest and posttest questions. Students' learning outcomes are evaluated using the posttest, which consists of 30 multiple-choice questions, each with five answer choices.

Hypothesis testing was conducted using the Independent-Sample T-test analysis. The determination of whether the null hypothesis (Ho) is accepted or rejected relies on interpreting the significance value derived from the SPSS version 20 analysis results. According to the criteria employed, if the significance value (Sig) is greater than 0.05, then Ho is accepted, indicating that there is no significant effect of treatment differences on the response variables.

Result and Discussion

The results and discussion are presented in two parts. Firstly, comparing pretest and posttest scores from both control and experimental classes for students' metacognitive abilities (Figure 1), and comparing pretest and posttest scores from both control and experimental classes for students' learning outcomes (Figure 2). Secondly, the comparison of inferential statistical test results. Both activities aim to provide a comprehensive view of the impact of using Project-Based Learning model with aquascape media on ecosystem lesson.

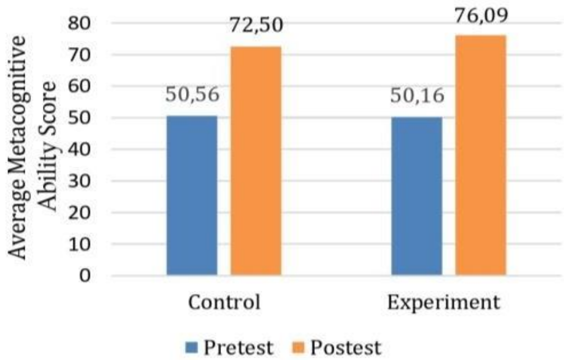

Figure 1. Comparison of pretest and posttest scores of metacognitive abilities from both classes

Figure 1 shows the average scores of students' metacognitive abilities in the control class, which are 50.56 for the pretest and 72.50 for the posttest, with a difference of 21.94 points. The average scores of metacognitive abilities in the experimental class are 50.16 for the pretest and 76.09 for the posttest, with a difference of 25.95 points.

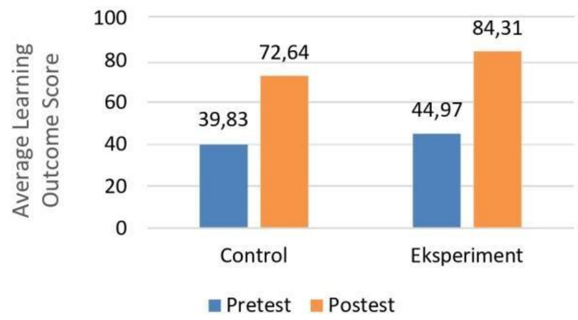

Figure 1. Comparison of pretest and posttest scores of learning outcomes from both classes

Figure 2 illustrates the average scores of students' learning outcomes in the control class, which are 39.83 for the pretest and 72.64 for the posttest, with a difference of 32.81 points. The average scores of learning outcomes in the experimental class are 44.97 for the pretest and 84.31 for the posttest, with a difference of 58.36 points.

Table 4. Results of the Normality test of Metacognitive Abilities and Learning Outcomes

Variable	Class	Sig.
Metacognitive	Pretest Experiment	0.889
	Posttest Experiment	0.187
	Pretest Control	0.071
	Posttest Control	0.224
Learning Outcome	Pretest Experiment	0.374
	Posttest Experiment	0.168
	Pretest Control	0.052
	Posttest Control	0.074

*Shapiro Wilk, sig > 0.05 then the distribution is normal

Normality testing is conducted to determine whether the learning outcomes data obtained, specifically the pretest and posttest data, are normally distributed or not.

Table 5. Results of Homogeneity Test of Metacognitive Abilities and Learning Outcomes

Variable	F	DF1	DF2	Sig.
Metacognitive	1.641	3	132	0.183
Learning Outcome	2.315	3	132	0.079

*Levene, sig > 0.05 then the data is homogeneous

Based on the results of the Homogeneity test in the table above, it is known that the probability value p or Sig for Metacognitive is 0.183 and for Learning

Outcomes is 0.079. Because the sig. value > 0.05, it can be concluded that the homogeneity assumption is fulfilled. Because the assumptions of normality and homogeneity have been met, parametric analysis in the form of an independent sample t test was used to carry out statistical analysis.

Table 6. Independent-Sample T-Test Results for Metacognitive Abilities

Metacognitive	Group		P-Value
	Experiment (Mean ± SD)	Control (Mean ± SD)	
Pretest	50.156 ± 5.162	50.555 ± 6.716	0.786
Posttest	76.093 ± 5.953	72.500 ± 7.221	0.030

Based on the table above, it is found that for the pretest, the mean value for the experimental group is 50.156, while the mean value for the control group is 50.555. The experimental value is lower than the control value. Additionally, a p-value of 0.786 was obtained, which is >0.05, indicating that H0 is accepted and H1 is rejected. Therefore, it can be concluded that there is no significant difference in means between the experimental and control groups in the pretest.

For the posttest, the mean value for the experimental group is 76.093, while the mean value for the control group is 72.500. The experimental value is higher than the control value. Additionally, a p-value of 0.030 was obtained, which is < 0.05, indicating that H0 is rejected and H1 is accepted. Therefore, it can be concluded that there is a significant difference in means between the experimental and control groups in the posttest.

The students of class X at SMAN Idi Rayeuk, both in the experimental and control groups, have the same metacognitive abilities. This is evidenced by the pre- test data analysis of metacognitive abilities, which shows no difference in average scores between the experimental and control classes.

The post-test data analysis reveals a difference in the average metacognitive abilities between the control and experimental classes. This demonstrates that the implementation of the PjBL model based on aquascape media affects the students' metacognitive abilities. The use of this model not only has the potential to enhance students' understanding of the material but also their ability to recognize, manage, and control their own thinking processes (metacognition). Therefore, it can be concluded that the integration of aquascape media into the PjBL model can provide significant benefits in developing students' metacognitive abilities.

The application of the PjBL model based on aquascape media can influence students' metacognitive abilities for several interrelated reasons. First, the use of aquascape media stimulates students' interest and engagement in learning. The improvement in students' metacognitive abilities after implementing the PjBL model based on aquascape media can be explained by several factors. First, PjBL provides opportunities for students to actively engage in the learning process through project work. Second, the attractive aquascape media can increase students' motivation and interest in learning, making them more enthusiastic about the learning process. Third, the process of completing the aquascape project requires students to plan, organize, and evaluate their projects, thus training their metacognitive abilities.

Engaging visual media like aquascapes has a strong appeal, motivating students to actively participate in exploration and problem-solving. This aligns with the research by Utaminingtyas et al. (2020), which states that interest and enjoyment in a learning activity can enhance individuals' enthusiasm for participating in classroom learning. Thus, through the use of aquascape media, students not only actively acquire knowledge but also significantly strengthen their metacognitive skills.

Secondly, the PjBL approach provides opportunities for students to take an active role in their learning process. In this context, students not only receive information from the teacher but also engage in real projects that require problem-solving, collaboration, and independent exploration. This can increase their awareness of effective learning strategies and promote reflection on their learning process.

This is consistent with Nasar et al. (2020), who state that the PjBL model helps students learn independently and take responsibility for their own learning. Furthermore Rumahlatu et al. (2019) mention that the PjBL model has better potential for improving students' metacognitive skills compared to conventional learning models. Project-based learning trains students to become independent learners in planning projects, taking responsibility for project execution, and reporting the results obtained, thereby developing their metacognitive skills. Thus, the combination of engaging aquascape media and a student-centered learning model allows students to effectively develop and enhance their metacognitive abilities.

Table 7. Independent-Sample T-Test Results for Learning Outcomes

Metacognitive	Group		P-Value
	Experiment (Mean ± SD)	Control (Mean ± SD)	
Pretest	44.968 ± 11.939	39.833 ± 9.473	0.052
Posttest	84.312 ± 7.672	72.638 ± 7.892	0.000

Based on the table above, it is found that for the pretest, the mean value for the experimental group is 44.968, while the mean value for the control group is 39.833. The experimental value is higher than the control value. Additionally, a p-value of 0.052 was obtained, which is >0.05, indicating that H0 is accepted and H1 is rejected. Therefore, it can be concluded that there is no significant difference in means between the experimental and control groups in the pretest. For the posttest, the mean value for the experimental group is 84.312, while the mean value for the control group is 72.638. The experimental value is higher than the control value. Additionally, a p-value of 0.000 was obtained, which is <0.05, indicating that H0 is rejected and H1 is accepted. Therefore, it can be concluded that there is a significant difference in means between the experimental and control groups in the posttest.

The students of class X IPA at SMAN 1 Idi Rayeuk have uniform initial abilities, as evidenced by their scores and statistical analysis showing no significant differences between the control and experimental classes. The post-test data analysis reveals a significant difference in the average scores between the control class and the experimental class that applied the PjBL model based on aquascape media. This provides concrete evidence that the implementation of this learning model has a positive impact on student learning outcomes. Furthermore, the average scores achieved by students also show significant differences, with the experimental class displaying higher average scores compared to the control class.

The contributing factor can be explained by the applied learning model. The PjBL model based on aquascape media allows students to actively engage in the learning process. Students are given the freedom to design and carry out their learning projects in groups according to the themes they choose. As described by Chen et al. (2019), the PjBL model has great potential to make the learning experience more interesting and meaningful for students, encouraging them to be more active in learning since the teacher's role is only as a facilitator, providing ease, and evaluating the significance of the projects in students' lives.

This project is not just an assignment but also a deep exploration of one of the ecosystems they study, namely the aquatic ecosystem. Thus, during the project execution, students are not just completing tasks but are also directly learning about the subject matter they are investigating. This aligns with Yulianto (2016) who mention that the PjBL model is a comprehensive learning approach involving students in collaborative investigations. Furthermore Malawati et al. (2016) state that through the PjBL model, students can practice 21st-century skills as they go through a long process of inquiry, answering questions from complex problems or challenges.

The learning values derived from this project do not end at the completion stage. The final project presentation also plays a crucial role in measuring students' understanding. The presentation results demonstrate a good understanding of how all ecosystem components interact within the miniatures they create. Thus, these results not only meet academic assessment criteria but also reflect a broader understanding of ecological concepts acquired by the students. This is consistent with the findings of Choi et al. (2019), who explain that the PjBL model can show better concept mastery in students compared to those facilitated by discovery learning. Furthermore, Supiandi et al. (2016) in their research state that the PjBL model is effective in improving cognitive learning outcomes and life skills.

Overall, the learning model used in this research has broad implications for constructivist learning theory. By giving student's, the freedom to explore and construct their knowledge through direct experience, this learning model effectively facilitates a better and more sustainable learning process.

Conclusion

Based on the research findings and discussions, the implementation of the Project-Based Learning (PjBL) model using aquascape media has a positive impact on the metacognitive abilities and learning outcomes of grade X students at SMA Negeri 1 Idi Rayeuk in natural sciences. The results and discussions of this study also indicate that the PjBL model with aquascape media can be effectively applied in ecosystem learning. Furthermore, the study emphasizes the importance for teachers and schools to provide learning freedom to students so they can optimally explore their ideas and engage more deeply in the learning process.

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Author Contributions

Linda Murisqa: responsible for overall research, drafting and submitting articles, collected field data and analyzing data; Safrida: revised writing and validated field finding data;

Muhibbuddin: Proofreading draft articles; Cut Nurmaliah: Proofreading draft articles; Abdullah: collecting literacy.

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Conflicts of Interest
The authors declare that there is no conflict of interest regarding the publication of this paper.

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