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FROM PROJECT TO CRITICAL THINKING: FOOD CHAIN LEARNING IN PRIMARY SCHOOLS

Silvi Juwita Hasim, Marleny Leasa * and Johanes Pelamonia

Elementary School Teacher Education Study Program, Faculty of Teacher Training and Education, Pattimura University, Ambon, Maluku, Indonesia.
* Corresponding Author

ORCID Details
Silvi Juwita Hasim: https://orcid.org/0009-0009-8135-6853
Marleny Leasa: https://orcid.org/0000-0003-0718-3447
Johanes Pelamonia: https://orcid.org/0000-0002-8316-4216

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ABSTRACT

Critical thinking is an essential skill in 21st-century learning; however, science education in primary schools still faces challenges in encouraging students to analyze cause-and-effect relationships, evaluate changes, and understand the interconnections among ecosystem components. In the topic of food chains, the concepts of energy flow and relationships among organisms are also relatively complex, requiring active and contextualized learning. This study aimed to analyze the effect of the Project-Based Learning (PjBL) model on fifth-grade students' critical thinking skills in learning about food chains. The study employed a quantitative approach using a quasi-experimental method with a non-equivalent control group design. The population consisted of 131 fifth-grade students at SD Negeri 79 Ambon, with Class V-A comprising 24 students as the experimental group and Class V-B comprising 23 students as the control group. Data were collected using a structured essay test that had been established as valid and reliable and were analyzed using descriptive statistics, normality and homogeneity tests, and an independent-samples t-test at a significance level of 0.05. The results showed that students' critical thinking skills in the experimental group increased to the very high category, whereas those in the control group remained in the moderate category. The t-test yielded a significance value of $0.013 < 0.05$, indicating a significant effect of the PjBL model on students' critical thinking skills. The implementation of a Food Chain diorama project encouraged students to identify problems, plan activities, evaluate information, formulate arguments, and draw logical conclusions. Thus, PjBL had a positive and significant effect on students' critical thinking skills. Teachers are encouraged to implement PjBL with appropriate guidance, while schools should provide adequate facilities and teacher training. Future research may expand the study in terms of research settings, duration, and learning topics.

Keywords: Project-Based Learning; Critical Thinking; Food Chain; Primary School

1 INTRODUCTION

Twenty-first-century education focuses not only on the transfer of knowledge but also on equipping students with relevant skills, such as problem-solving, collaboration, and creativity, which are essential for addressing the dynamics of an ever-changing world. Education in this era is fundamentally aimed at developing learners who are critical, adaptive, creative, and independent in addressing various instructional challenges encountered in schools (Graesser et al., 2018). Education requires well-planned and structured learning processes. One important component of instructional planning is the selection of appropriate learning methods, which directly influences the success of students' learning processes (Mohiuddin et al., 2020). In the context of primary education, science learning is considered capable of significantly improving the quality of education by providing students with various hands-on experiences and reflective activities. Students are engaged in learning activities based on their real-life experiences, which can subsequently be reflected upon and connected to their everyday lives (Howes, 2008). To develop scientific literacy and prepare students to face the challenges of the global era, one of the key cognitive competencies that urgently needs to be fostered from an early age is critical thinking skills.

Critical thinking skills should be developed from an early age, particularly at the primary school level, because this is a crucial stage in which students' fundamental patterns of thinking begin to develop. Developing primary school students' critical thinking skills so that they can become responsible citizens and effectively address the challenges of the 21st century is one of the key missions of education (Bremnes et al., 2026). Since the mid-20th century, philosophers, psychologists, and educators have attempted to formulate a single definition of critical thinking; however, no scientific consensus has yet been reached, given that critical thinking is a highly complex concept. The literature on critical thinking distinguishes several types of components, including cognitive components (analytical and evaluative skills) and metacognitive components (self-regulation), epistemic components (knowledge of the subject, strategies, and cognitive mechanisms), and dispositional components (motivation and attitudes) (Schöpfer, 2025). In accordance with theories of cognitive development, children at the concrete operational stage begin to develop the ability to think logically and understand cause-and-effect relationships, although their reasoning remains largely oriented toward concrete phenomena (Apriliana & Anggrella, 2024). Conceptually, Ennis (2011), defines critical thinking as a conscious effort to employ cognitive skills or strategies to achieve a particular purpose, or as a process of making realistic, analytical, and reasonable decisions (Vincent-Lancrin, 2023). Critical thinking is also an organized process of problem-solving that involves a range of mental activities, including students' ability to formulate problems, express opinions or arguments, evaluate information, and make decisions (Oplatka, 2026).

Selain itu, in elementary science learning, particularly in the context of food chains, critical thinking skills are essential to ensure that students not only develop an in-depth understanding of the concepts but are also able to analyze energy flow, understand relationships among living organisms, and recognize the effects of changes in one component on the balance of an ecosystem. Mastery of ecosystem concepts, such as food webs, also plays an important role in helping students understand the complexity of interactions among living organisms and the interdependent relationships that occur within an ecosystem (Mambrey et al., 2022). Understanding the relationships among organisms and the flow of energy within an ecosystem is an important component of biology learning; however, these concepts are often difficult for students to understand. Interactions among organisms and energy transfer are fundamental processes that sustain life and maintain ecosystem balance. In this context, the ability to interpret food chains and food webs is important because it helps students understand patterns of relationships, interactions, and energy flow among organisms within an ecosystem. Research by Preston (2018) showed that food webs are a complex concept for primary school students, even though their diagrams may appear simple. Students experience various difficulties in interpreting these diagrams, particularly in determining where to begin reading, following the pathways connecting organisms, and understanding the meaning of arrows. Many students still interpret arrows merely as indicating direction or representing a "who eats whom" relationship, rather than understanding them as representations of the flow of energy and matter within an ecosystem.

This understanding is important for enabling students to connect the concepts they have learned with various ecological phenomena occurring in their surrounding environment. Therefore, learning about food chains should ideally encourage students to analyze cause-and-effect relationships, evaluate changes within ecosystems, and develop a more meaningful conceptual understanding. However, this ideal condition remains highly contradictory to the realities observed in the field, where students' abilities to understand concepts and engage in critical thinking continue to face various challenges. The Project-Based Learning (PjBL) model adopts an active learning approach, which can be broadly defined as learning that connects technology with everyday life problems familiar to students or with school-based projects (James et al., 2020). This innovative instructional model has several primary objectives, including using project work as a means of achieving subject-specific competencies, positioning students as active learners, encouraging initiative and exploration, providing opportunities to apply what they have learned, and enabling students to present and evaluate their performance (Kokotsaki et al., 2016). Another distinctive characteristic of this learning model is the production of a tangible product in the form of goods or services, such as designs, schematics, written works, artworks, or technological products, as a manifestation of students' learning outcomes. The effectiveness of implementing PjBL in teaching food web concepts has been shown to have positive effects on students' conceptual understanding, collaborative skills, and communication skills at the primary school level (Chen, 2018). Through these activities, students become more actively engaged in the learning process and develop their critical thinking skills.

The implementation of the PjBL model can also create meaningful learning by directly connecting food chain concepts with students' real-life contexts. Projects that are relevant to students' empirical experiences can encourage exploration and discovery, while involving students in project planning and theme selection can strengthen their sense of ownership of the learning process (Markula & Aksela, 2022). Based on the literature, numerous previous studies have examined the capacity of the PjBL model to foster critical thinking skills among primary school students. One such study by Almulla (2020), concluded that the implementation of PjBL enables students to engage actively in projects relevant to their everyday lives, accommodate differences in abilities and learning styles, and enhance their critical thinking skills. Nevertheless, despite the various previous studies evaluating innovative project-based learning models, their implementation still requires deeper strengthening of their instructional function. This is supported by the findings of Yao et al. (2026), who suggested that PjBL has so far tended to function primarily as an approach that helps students describe and analyze learning materials, reflect on the learning process, and prepare project presentations. PjBL is effective in supporting creativity and the development of conceptual understanding through iterative, problem-based, collaborative, and reflective learning; however, its effectiveness needs to be balanced with appropriate management of students' cognitive load.

2 METHOD

The study employed a quantitative research approach using a quasi-experimental method. This experimental approach was applied to compare two groups of research subjects in order to determine whether a causal relationship existed between the instructional treatment provided by the researcher and the resulting outcomes (Lashley, 2017; Xu et al., 2021). The specific research design employed in this study was the Non-Equivalent Control Group Design. Under this design, the research subjects were not randomly assigned to groups; rather, two existing classes were involved as separate groups. The first group served as the experimental group and received an intervention using the PjBL model, while the second group served as the control group and received conventional instruction using the learning materials and resources provided by the school. Both groups were administered a pretest prior to the intervention and a posttest following the intervention to measure students' critical thinking skills.

This study was conducted among fifth-grade students at SD Negeri 79 Ambon. The population comprised all fifth-grade students enrolled at SD Negeri 79 Ambon, distributed across three parallel classes (V-A, V-B, and V-C), with a total of 131 students. A random sampling technique was employed to select the classes for the study. Based on this procedure, two classes from the fifth-grade population were selected as the sample units. Class V-A, consisting of 24 students, was assigned as the experimental group, while Class V-B, consisting of 23 students, was assigned as the control group.

Data collection in this study relied on a primary instrument in the form of a student critical thinking skills test, which was administered at both the pretest and posttest stages. The instrument consisted of a written test comprising structured essay questions developed based on indicators of critical thinking skills. Before the instrument was administered for actual data collection, a pilot test was conducted outside the research sample involving 32 sixth-grade students from Class VI-A at SD Negeri 79 Ambon. The quality of the test items was evaluated through validity and reliability testing using SPSS version 22. The validity criteria of the test items were determined based on the comparison of the calculated r value to the r table value at a significance level of 5% with degrees of freedom df = N-2 = 30, so that the r table value was obtained at 0.3494. In addition, the validity of the test items was also evaluated based on the Significance value (2-tailed) < 0.05. The test results on 11 essay test items showed that 10 test items were declared valid because they had a calculated value > rtable, and 1 test item was declared invalid because it had a calculated r value < rtable. Furthermore, the reliability test of the valid test items yielded a Cronbach's Alpha coefficient of 0.702. This value exceeded the standard reliability threshold of 0.60; therefore, the instrument was considered reliable and suitable for use as a field data collection instrument.

The field data were analyzed quantitatively to assess the critical thinking performance of students in the experimental and control groups. Students' critical thinking ability was calculated based on the percentage of achievement for each indicator using a conversion formula based on the raw score relative to the maximum possible score. The resulting percentages for each critical thinking indicator were interpreted according to the rubric developed by Ermayanti & Sulisworo (2016) and classified into five categories. A percentage of $81.25\% < X \leq 100\%$ was classified as very high, $71.50\% < X \leq 81.25\%$ as high, $62.50\% < X \leq 71.50\%$ as moderate, $43.75\% < X \leq 62.50\%$ as low, and $0 < X \leq 43.75\%$ as very low. Before drawing conclusions based on statistical hypothesis testing, the assumptions underlying the analysis were first examined. Data normality was assessed using a significance criterion of > 0.05, while the homogeneity of variances was tested using a significance criterion of > 0.05. After these assumptions were satisfied, the research hypothesis was tested using an independent-samples t-test (Independent Sample T-Test) to determine whether the PjBL model had a statistically significant effect on students' critical thinking skills at an alpha significance level of 0.05.

3 RESULTS

PThe critical thinking skills of fifth-grade students at SD Negeri 79 Ambon were assessed using a structured essay test administered before the intervention (pretest) and after the intervention (posttest). The assessment involved an experimental group (Class V-A, consisting of 24 students) taught using the PjBL model and a control group (Class V-B, consisting of 23 students) taught using conventional instruction. The pretest and posttest scores of students' critical thinking skills in both groups are presented in Figure 1.

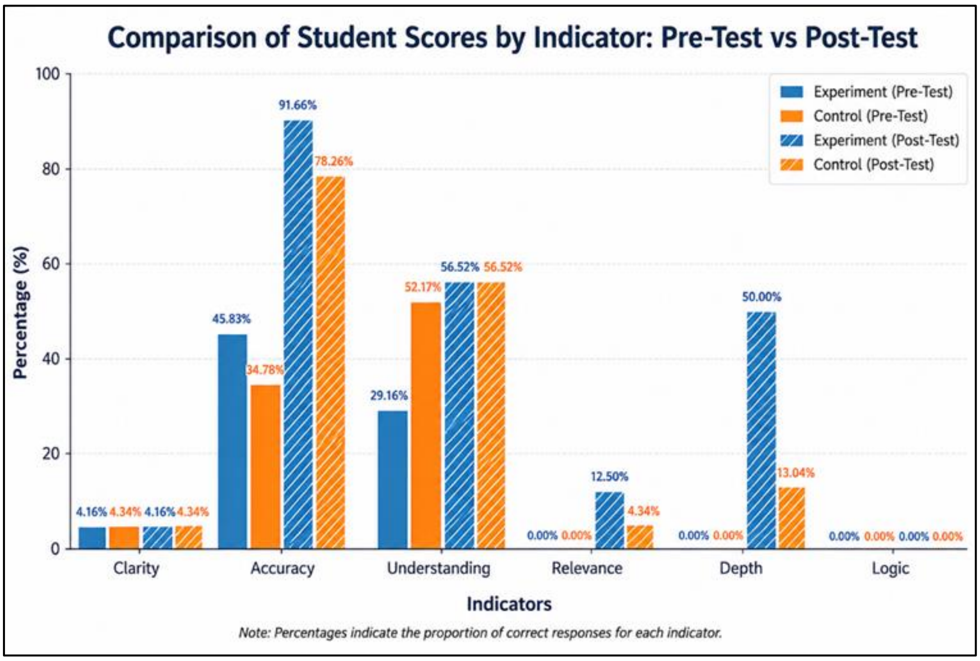

Figure 1: Pretest and posttest results of students' critical thinking skills

Based on the data presented in Figure 1, the descriptive results indicate that the initial critical thinking skills of students in the experimental and control groups had similar characteristics before the instructional intervention was administered. However, after the teacher implemented the learning process using the instructional model developed by the researchers, a notable difference in cognitive performance was observed. The experimental group, which received the intervention through the project-based learning syntax involving the collaborative construction of a food chain diorama, experienced a significant improvement, reaching the very high category within the interval of $81.25 < X \leq 100$. In contrast, the control group, which participated in one-way learning using the school's conventional instructional materials, showed only a limited improvement in critical thinking skills and remained within the Moderate category, with an interval of $62.50 < X \leq 71.50$. Before drawing statistical conclusions regarding the effect of the instructional model, the critical thinking learning outcome scores of the two groups were first assessed for suitability through a series of prerequisite tests for data analysis.

Table 1: Shapiro–Wilk Test of Normality for Pretest and Posttest Scores

Group	n	Pretest, W	p	Posttest, W	p
Control	23	0.929	0.105	0.945	0.226
Experimental	24	0.921	0.061	0.966	0.560

Based on the normality test presented in Table 1, the control group obtained significance values of 0.929 for the pretest and 0.945 for the posttest. Both values were greater than $\alpha = 0.05$, indicating that the data for the control group were normally distributed. Meanwhile, the experimental group obtained significance values of 0.921 for the pretest and 0.966 for the posttest. Both values were also greater than $\alpha = 0.05$, indicating that the data for the experimental group were normally distributed.

Table 2: Levene's Test for Equality of Variances

Outcome	Levene's *F*	df1	df2	*p*
Test scores	3.226	1	45	0.079

After the normality test was conducted, the analysis was continued with a homogeneity test, as presented in Table 2, using the pretest scores of the control and experimental groups. The homogeneity test, conducted using the Levene statistic, yielded a significance value of 0.085. Since this value was greater than $\alpha = 0.05$, it was concluded that the variables in the two groups were homogeneous. Based on the results of the normality and homogeneity tests, it can be concluded that the data were normally distributed and that the variables between the two groups were homogeneous. Therefore, the assumptions for the parametric analysis were satisfied, allowing the analysis to proceed with an independent-samples t-test. Before conducting the independent-samples t-test to determine whether the PjBL model had an effect on students' critical thinking skills, the research hypotheses were formulated as follows: H_0: The PjBL instructional model has no effect on students' critical thinking skills. H_a: The PjBL instructional model has an effect on students' critical thinking skills.

Table 3: Independent-Samples *t*-Test Comparing the Control and Experimental Groups

Comparison	*t*	df	*p*	Mean Difference	95% CI of the Difference
Control vs. Experimental	−2.592	45	0.013	−7.531	[−13.383, 1.678]

Note. An independent-samples *t*-test was conducted assuming equal variances based on Levene's test, F (1, 45) = 3.226, p = .079. p-values are two-tailed. CI = confidence interval.

Based on the results of the independent-samples t-test, the Sig. (2-tailed) value was 0.013, which was lower than α = 0.05. Therefore, H_0 was rejected and H_a was accepted, indicating that the Project-Based Learning (PjBL) model had a significant effect on students' critical thinking skills in the food chain topic.

4 DISCUSSION

After all prerequisite analyses, including tests of data normality and homogeneity of variances, were confirmed to be adequately satisfied, the research hypothesis was tested using a parametric statistical procedure, namely the independent-samples t-test. Statistically, the hypothesis testing was conducted to examine the null hypothesis (H_0), which stated that there was no significant effect of the PjBL model on students' critical thinking skills, against the alternative hypothesis (H_a), which stated that the use of the PjBL model had a significant effect on students' critical thinking skills in science learning. The statistical decision rule was based on the significance value. If the obtained significance value was less than 0.05, H_0 was rejected and H_a was accepted. Based on the independent-samples t-test analysis of the students' final scores (posttest), the obtained significance coefficient was below the predetermined significance level ($p < 0.05$). This empirical finding led to the statistical decision to reject the null hypothesis (H_0) and accept the alternative hypothesis (H_a). Therefore, the hypothesis testing results empirically demonstrated that the implementation of the PjBL model had a significant effect on students' critical thinking skills in the Food Chain topic.

Based on the inferential statistical analysis of the field data, the empirical findings of this study indicate that the implementation of the PjBL model had a significant positive effect on students' critical thinking skills in the food chain topic. Evidence of this effect was demonstrated by the difference in cognitive performance between the experimental group (Class V-A), which was taught using the PjBL model, and the control group (Class V-B), which received conventional instruction using the learning materials provided by the school. Through inferential statistical testing using an independent-samples t-test, the obtained significance coefficient was below the predetermined significance level ($p < 0.05$), leading to the rejection of the Null Hypothesis (H_0) and acceptance of the Alternative Hypothesis (H_a). The superior critical thinking performance observed in the experimental group can be directly attributed to the effectiveness of the operational characteristics of the PjBL model, which positions students as active learners (Loyens et al., 2023). Throughout the experimental process, the implementation of this project-based learning model successfully transformed the classroom environment from one initially dominated by one-way teacher lectures into student-centered instructional activities. This condition is highly relevant to the cognitive developmental theory of elementary school-aged children, who are generally at the concrete operational stage, during which they begin to develop logical reasoning and understand cause-and-effect relationships through the manipulation of real objects in their surrounding environment (Kokotsaki et al., 2016). In this study, fifth-grade students in Class V-A were provided with concrete learning experiences through a group project involving the construction of a Food Chain diorama.

Each stage of the PjBL model's instructional sequence was found to make a specific contribution to stimulating students' critical thinking indicators. During the phase of formulating the essential question, students were encouraged to identify real-world problems, formulate questions, and express their initial opinions or arguments regarding ecosystem components. The findings of Roth & Reynolds (2020) , involving students in Grades 3 to 7 on the topic of marine ecosystems, showed that the implemented learning approach successfully improved students' understanding of ecosystem services, particularly those relevant to marine conservation, while also strengthening their understanding of the roles of organisms within food webs. The effectiveness of the learning approach was also reflected in students' affective responses, with 82% of participants reporting that they liked or strongly liked the activities. Furthermore, during the stages of designing the project plan and developing a schedule for constructing the diorama, students were mentally required to utilize group skills and cognitive strategies to achieve the project objectives realistically. This group planning process trained students to make analytical and rational decisions regarding task distribution and the selection of appropriate tools and materials for the project. The collaborative construction of the diorama also contributed positively to meaningful social interactions among students. As students actively worked together to assemble components representing producers, consumers, and decomposers, they exchanged information and jointly evaluated scientific evidence. The characteristic of the PjBL model that requires students to produce a tangible product in the form of a physical design provides broad opportunities for exploration (Yarmi et al., 2026). The peak of critical thinking stimulation occurred when students tested their products and evaluated their learning experiences by presenting the Food Chain diorama in front of the class. Through these presentation sessions and interactive discussions, students were independently trained to defend scientific arguments, respond to critical questions, and draw structured conclusions about the relationships among food chains and ecosystem balance in a logical manner.

The findings from this classroom further reinforce the theoretical literature presented in this manuscript regarding the effectiveness of active, project-based learning models at the elementary school level. The implementation of the PjBL model was empirically shown to have a highly positive effect on improving students' understanding of science concepts, collaborative skills, and communication abilities. Through a series of projects relevant to their empirical experiences, students did not merely memorize ecosystem concepts theoretically but actively engaged both emotionally and cognitively in the learning process. This approach accommodated differences in students' learning styles while simultaneously enhancing their critical thinking skills. Although the PjBL model demonstrated a substantial effect, an in-depth analysis of students' answer sheets indicated that project-based activities still require purposeful and structured teacher guidance. Strengthening the teacher's instructional role remains essential to ensure that project activities do not merely become visual representations of the learning material or focus solely on preparing group presentations. Teachers should continue to guide students toward engaging in deeper analysis of the underlying science concepts. Overall, this synthesis of the findings confirms that the implementation of the PjBL model constitutes an important determinant that contributes significantly to improving the quality of students' critical thinking processes.

5 CONCLUSION

Based on the overall findings and discussion presented, it can be validly concluded that the implementation of the PjBL model had a positive and significant effect on students' critical thinking skills, particularly in the food chain topic. This significant effect was empirically demonstrated through inferential statistical analysis using an independent-samples t-test, which yielded a significance coefficient below the required statistical significance threshold. The instructional activities involving the construction of a Food Chain diorama effectively improved the cognitive performance of students in the experimental group (Class V-A), bringing their performance into the Very High category, substantially exceeding that of the control group (Class V-B), which was taught using a conventional one-way instructional approach and reached only the Moderate category. This project-based learning process successfully transformed the classroom environment into a student-centered setting, encouraged inclusive collaborative work, and trained students' cognitive abilities to formulate problems, evaluate scientific evidence, express opinions, and draw logical and analytical conclusions.

Based on the empirical findings and conclusions of this study, several practical and operational recommendations can be proposed to optimize the quality of learning at the elementary school level. For educators, particularly classroom teachers, the PjBL model should be integrated and implemented as an alternative innovative instructional strategy in science learning to minimize students' tendency toward passive memorization while fostering higher-order thinking skills from an early age. School management and educational institutions are also expected to provide adequate structural support, including the provision of supporting learning facilities and the facilitation of regular teacher training on the development of active, project-based learning models to support the comprehensive implementation of the Kurikulum Merdeka. Finally, future researchers are encouraged to expand the research setting, extend the duration of the intervention, and investigate the effects of the PjBL model on critical thinking skills across other science topics with varying levels of complexity.

STATEMENTS ON COMPLIANCE WITH ETHICAL STANDARDS

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The authors declare no conflicts of interest regarding this manuscript.

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