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Building children's scientific literacy through nature based problem based learning integrated with naturalistic intelligence

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Abstract

This study investigates the effectiveness of a Naturalistic Intelligence Based Problem Based Learning model in improving scientific literacy among elementary school students. A quantitative experimental approach was used, employing a one group pretest posttest design involving 20 fourth grade students from SD Muhammadiyah Inovatif. Scientific literacy was measured across four domains conceptual understanding, explanation of scientific phenomena, data interpretation, and application of scientific knowledge in everyday situations using a validated instrument that demonstrated acceptable reliability. The intervention combined inquiry based tasks with direct engagement in natural environments, enabling students to approach scientific problems through observation, exploration, and contextual reasoning. Data analysis was conducted using a paired sample t-test to determine the impact of the learning model. The findings revealed a notable improvement in scientific literacy following the intervention. The mean difference between the pretest and posttest scores was 15.48 points, with a standard deviation of 7.84 and a standard error of 1.71. The 95% confidence interval ranged from 19.04 to 11.91, and the t-value of −9.046 (df = 20) with $p < 0.001$ confirmed that the learning model produced a statistically significant effect. These results indicate that integrating naturalistic intelligence within the PBL framework supports deeper inquiry, enriches students' scientific thinking, and enhances their ability to relate scientific concepts to real-life contexts. In light of ongoing curriculum reforms that promote student-centered and context-oriented learning, this study provides meaningful insights for teachers and schools seeking to strengthen science instruction in primary education. Wider application of this model is recommended to further advance students' scientific literacy.

Keywords

Scientific literacy, Problem based learning, Elementary schools

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Introduction

Scientific literacy has long been a central concern in science education research, particularly at the elementary school level. In this context, scientific literacy is generally understood as students' ability to understand scientific concepts, explain natural phenomena in a reasoned manner, interpret basic data and evidence, and apply scientific knowledge in everyday situations [1]. At the elementary level, these abilities are considered important because they contribute to the early development of scientific ways of thinking that support learning at later stages [2]. A growing body of research indicates that fostering scientific literacy in early education continues to face challenges, especially in relation to how science learning is designed to connect with students' lived experiences.

In many elementary school settings, science instruction remains largely oriented toward textbook based explanations and teacher led delivery. While this approach plays a role in introducing foundational scientific concepts, it often provides limited opportunities for students to relate these concepts to observable phenomena in their surroundings. As a result, students' understanding of science may remain largely conceptual, without sufficient support for applying knowledge in meaningful contexts. This situation has encouraged researchers to explore instructional approaches that place greater emphasis on student engagement and contextual learning [3] [4].

One instructional approach that has been widely examined in science education research is Problem Based Learning (PBL). From a theoretical perspective, PBL is grounded in constructivist views of learning, which emphasize learners' active role in constructing knowledge through engagement with problems. Empirical studies have reported that PBL can support the development of conceptual understanding and critical thinking skills, particularly when the problems presented are contextual in nature [5] [6]. At the elementary level, PBL is commonly implemented through group discussions, guided exploration of learning resources, and the formulation of simple solutions to presented problems.

Alongside PBL, environment based learning has also received attention in elementary science education. This approach utilizes the surrounding environment as a learning resource, allowing students to observe natural phenomena directly. Several studies suggest that environment-based learning can help students recognize the relationship between scientific concepts and everyday reality, as well as increase their engagement in the learning process [7] [8]. However, in practice, environmental activities are often implemented as supplementary experiences and are not always systematically integrated into a structured problem-solving framework.

Research on naturalistic intelligence offers an additional perspective for understanding the relationship between science learning and students' interaction with the natural environment. Naturalistic intelligence refers to an individual's capacity to recognize, classify, and understand natural phenomena and environmental patterns. Some studies indicate that students with stronger tendencies in naturalistic intelligence are more responsive to learning activities that involve observation and exploration of nature [9] [10]. Nevertheless, in much of the existing research, naturalistic intelligence has been treated primarily as an individual learner characteristic, rather than as a foundational principle for designing science learning models.

When viewed collectively, previous studies have contributed valuable insights into science teaching and learning, yet certain limitations remain evident. PBL provides a relatively structured framework for problem solving, but its implementation in elementary classrooms often relies on text-based problems or simplified scenarios. In contrast, environment based learning and approaches related to naturalistic intelligence offer more authentic learning experiences, but these are not always accompanied by clearly articulated inquiry structures. In addition, learning outcomes in many studies have focused predominantly on cognitive achievement, while scientific literacy as a multidimensional construct has not always been examined comprehensively.

Based on these considerations, integrating Problem Based Learning with an approach that takes naturalistic intelligence into account appears worthy of further investigation. Within this framework, learning problems are designed to emerge from phenomena in students' immediate environments, so that problem solving processes are supported by direct observation and exploration [11]. Such an approach allows students to develop scientific understanding through empirical experiences while remaining within a structured learning sequence.

Conceptually, this approach positions the environment as both a learning context and a source of information in the inquiry process. Learning therefore involves not only discussion and abstract reasoning, but also direct interaction with natural objects and events. This orientation aligns with the view that science learning at the elementary level should provide concrete experiences to help students connect scientific concepts with situations they encounter in their daily lives. While various studies have examined the use of *Problem Based Learning* or *environment based learning* independently, few have systematically integrated naturalistic intelligence into the PBL framework as a core pedagogical design principle. Most prior works have conceptualized naturalistic intelligence only as a learner trait that influences preferences or engagement, not as a structured instructional foundation for inquiry. In contrast, this study explicitly combines problem-solving mechanisms of PBL with empirical engagement in natural environments, thus proposing a novel instructional model termed *Naturalistic Intelligence–Based PBL*. This synthesis reflects both conceptual renewal and practical innovation in the design of science learning for young learners, especially in developing nations undergoing curriculum transformation toward competency-based and context-rich education.

Based on this conceptual framework, the present study aims to examine the effect of implementing a Naturalistic Intelligence Based Problem-Based Learning model on elementary students' scientific literacy. Scientific literacy in this study encompasses conceptual understanding, the ability to explain scientific phenomena, data interpretation skills, and the application of scientific knowledge in everyday contexts.

To achieve this objective, a quantitative approach employing a one-group pretest–posttest experimental design was used. The following sections describe the research methods in detail, followed by the presentation and discussion of the findings based on empirical evidence.

Method

This study employed a quantitative approach using a quasi-experimental design with a one-group pretest–posttest format to examine changes in students' scientific literacy following the implementation of a Naturalistic Intelligence–Based Problem Based Learning model. This design was selected to capture learning outcomes within an authentic classroom context without altering the existing instructional structure. The participants were 20 fourth-grade students from Muhammadiyah Innovatif Elemantary School who took part in the entire learning intervention as a single intact group. The instructional intervention was conducted over several science lessons and was structured according to the core stages of Problem Based Learning, including problem orientation, organization of learning activities, inquiry through environmental observation, data discussion, and reflective evaluation. Learning problems were derived from natural phenomena in the school environment, enabling students to engage in direct observation, simple data recording, and contextual reasoning, without the use of laboratory instruments requiring specific measurement tolerances. The research flow can be seen in Figure 1.

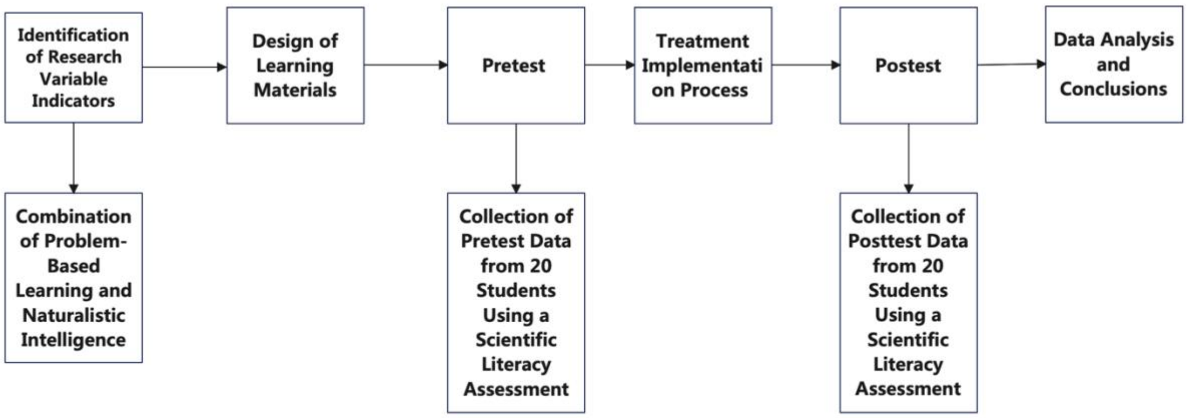

Figure 1. Research design and procedure

Data were collected using a scientific literacy test developed to assess four domains: conceptual understanding, explanation of scientific phenomena, data interpretation, and application of scientific knowledge in everyday contexts. The instrument was administered before the intervention (pretest) and after the completion of the learning activities (posttest). Content validity was established through expert review, and reliability analysis indicated acceptable internal consistency. Prior to hypothesis testing, the data were examined for normality to ensure the appropriateness of parametric analysis. Differences between pretest and posttest scores were then analyzed using a paired-sample t-test to determine the statistical significance of changes in students' scientific literacy following the intervention. The sequence of analytical procedures was aligned with the research objectives and provided a clear foundation for the presentation of results in the subsequent section.

Results and discussion

Results

Students' scientific literacy was measured before and after the implementation of the Naturalistic Intelligence Based Problem Based Learning model using a test instrument covering four domains: conceptual understanding, explanation of scientific phenomena, data interpretation, and application of scientific knowledge in everyday contexts. The pretest results indicated that students' initial scientific literacy levels were moderate, with relatively wide variation among individuals. Following the instructional intervention, posttest results showed an increase in scores for most students, accompanied by a more concentrated score distribution compared to the initial condition. Figure 2 illustrates the distribution of pretest and posttest data across scientific literacy aspects

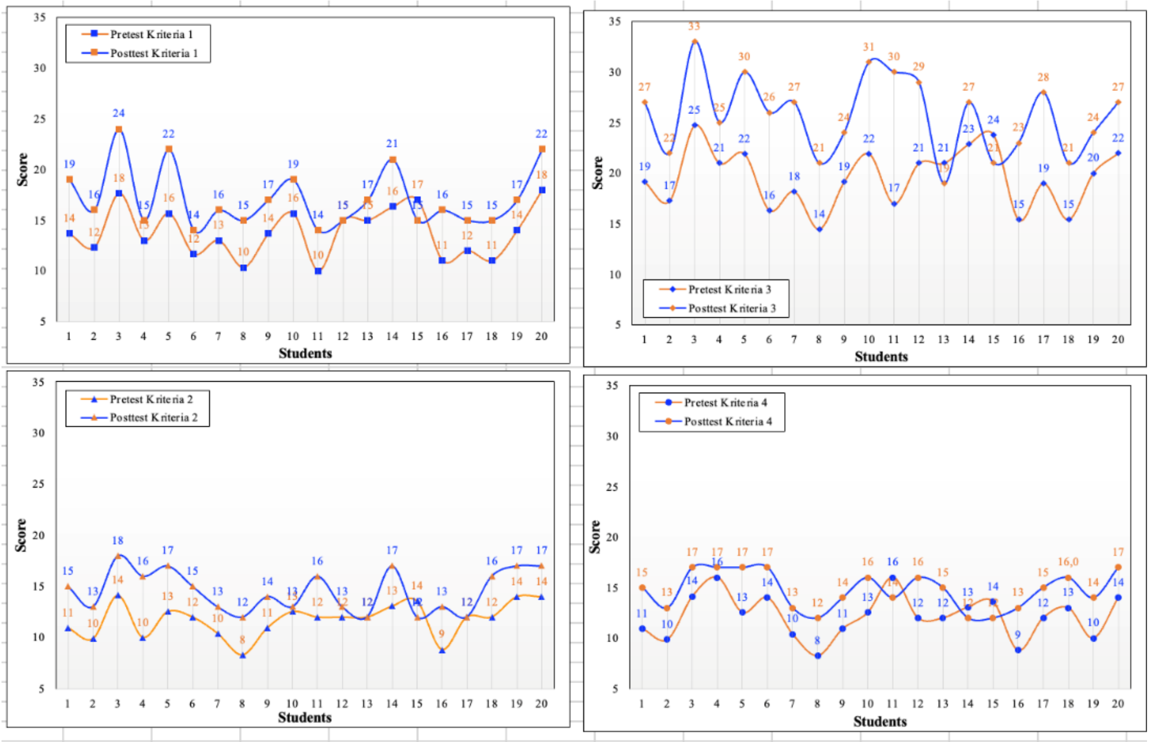

Figure 2. Distribution of pretest and posttest data across scientific literacy aspects

Descriptively, the mean scientific literacy score increased by 15.48 points from the pretest to the posttest. This increase indicates a change in students' scientific literacy after participation in the learning activities. To ensure the appropriateness of statistical analysis, a normality test was conducted on the pretest–posttest difference scores. The results showed that the data met the assumption of normality, allowing for the use of parametric statistical analysis.

Inferential analysis was performed using a paired-sample t-test to examine the significance of the difference between pretest and posttest scores. The results indicated a t-value of −9.046 with 20 degrees of freedom and a significance level of less than 0.001. The mean difference of 15.48 points was associated with a standard deviation of 7.84 and a standard error of 1.71. The 95% confidence interval for the mean difference ranged from 11.91 to 19.04, indicating that the observed improvement was statistically significant. Beyond statistical improvement, a qualitative review of the test results revealed several emerging learning themes supporting the quantitative patterns : (a) Conceptual Reinforcement. Students displayed greater consistency in explaining cause effect relationships of natural phenomena such as plant growth and water cycles. (b) Analytical Reasoning Learners. improved in interpreting observational data and could articulate logical explanations grounded in direct experience rather than rote recall. (c) Applied Understanding Students. increasingly related classroom knowledge to everyday issues, including environmental cleanliness, recycling, and weather patterns. (d) Collaborative Inquiry Skills. Observation notes indicated improvement in teamwork, questioning, and presentation clarity.

These thematic patterns underscore that the Naturalistic Intelligence–Based PBL model strengthened different domains of scientific literacy in mutually reinforcing ways.

When examined across the four domains of scientific literacy, improvements were observed in all measured aspects. Students demonstrated better conceptual understanding, increased ability to explain scientific phenomena, improved skills in interpreting simple data, and greater capacity to apply scientific knowledge to everyday situations. Although the magnitude of improvement varied slightly across domains, a consistent pattern of improvement was evident across all aspects of scientific literacy following the implementation of the learning model.

Discussion

The results of this study indicate a notable improvement in elementary school students' scientific literacy following the implementation of a Problem-Based Learning model grounded in naturalistic intelligence. This finding supports the premise that when learners engage with real and observable problems, they develop a more integrated understanding of scientific concepts across conceptual, procedural, and applied dimensions. Specifically, improvement across all four domains conceptual understanding, explanation of phenomena, data interpretation, and application suggests that the model nurtured students' scientific thinking as a coherent competence. This aligns with the multidimensional view of literacy proposed by PISA frameworks, where knowledge, skills, and context management coexist as interdependent capacities.

From a theoretical perspective, these findings are consistent with constructivist views of science learning, which emphasize that knowledge is actively constructed through learners' engagement and interaction with their learning environment. The Problem

Based Learning model provides a learning structure that encourages students to observe problems, engage in discussion, conduct investigations, and reflect on the solutions they generate [12]. When Problem Based Learning is integrated with a naturalistic intelligence-based approach, the process of knowledge construction becomes more contextualized, as learning problems are derived from real and familiar natural phenomena. This condition enables students to connect abstract scientific concepts with their own empirical experiences, resulting in learning outcomes that extend beyond declarative knowledge toward functional and applicable understanding [13] [14].

The findings of this study also reinforce previous research demonstrating the positive contribution of Problem Based Learning to the development of students' conceptual understanding and scientific thinking skills. However, much of the prior research has implemented Problem Based Learning using text-based problems or hypothetical scenarios, which tend to limit students' engagement with empirical data. In contrast, the present study demonstrates that when the natural environment is utilized as a source of learning problems and simple observational data, Problem Based Learning becomes more contextual and relevant for elementary school learners. Through direct observation of natural phenomena, students are not only trained to solve problems cognitively, but also to interpret data and apply scientific concepts in authentic situations. Thus, this study does not contradict earlier findings, but rather provides empirical refinement regarding the operationalization of Problem Based Learning in elementary science education.

Viewed from the perspective of naturalistic intelligence, the results suggest that direct interaction with the natural environment plays a strategic role in enhancing students' engagement and understanding in science learning. Unlike previous studies that have largely treated naturalistic intelligence as an individual learner characteristic, this research positions naturalistic intelligence as a principle of instructional design. The integration of naturalistic intelligence into the stages of Problem Based Learning offers a systematic framework for environment based learning activities, ensuring that observation and exploration of nature are not isolated experiences but are directly linked to the scientific problem-solving process. This instructional approach helps explain why improvements in scientific literacy were relatively evenly distributed across all measured aspects, as each stage of learning simultaneously fostered conceptual understanding, scientific reasoning, and real-world application.

The effectiveness of the learning outcomes is also closely related to the faithful and consistent implementation of the Problem Based Learning syntax within a naturalistic intelligence framework. All stages of the learning process ranging from problem orientation and organization of learning activities to individual and group inquiry, presentation of findings, and reflection were implemented systematically. Adherence to these stages ensured students' active engagement in a structured scientific problem-solving process. The problems presented were authentic and closely connected to students' everyday experiences, as they were derived from natural and environmental phenomena surrounding the learners. This condition encouraged students to construct scientific knowledge independently, develop inquiry skills, and articulate scientific explanations using their own language based on firsthand experience [15] [16].

Furthermore, learning activities conducted outside the classroom contributed substantially to increased student motivation and enthusiasm for learning [17] [18]. Natural environments provided concrete and interactive learning contexts, making scientific concepts more accessible and meaningful. Students' heightened enthusiasm was reflected in their increased participation in questioning, discussion, and exploration activities. This motivational aspect positively influenced scientific literacy development, as motivated students tended to engage more actively in connecting scientific concepts with real-world situations and demonstrated greater confidence in explaining observed phenomena. Thus, environment-based learning not only enhanced students' emotional engagement but also enriched their cognitive experiences in science learning [19].

Collaborative experimental activities also played a significant role in improving students' scientific literacy, particularly in relation to scientific process skills and conceptual understanding [20]. Through simple science experiments aligned with instructional topics, students were directly involved in applying scientific methods, including formulating questions and hypotheses, conducting observations and data collection, analyzing results, and drawing conclusions. Such direct involvement enabled students to recognize that scientific concepts are supported by empirical evidence, thereby fostering deeper and more meaningful understanding [21].

Despite the positive outcomes, the findings of this study should be interpreted with consideration of certain limitations. The one-group pretest–posttest design allows for the measurement of learning gains but does not include a comparison group to control for external influences. In addition, the limited number of participants and the focus on a single elementary school context constrain the generalizability of the findings. Nevertheless, the consistency between the research objectives, instructional design, measurement instruments, and observed outcomes indicates that the reported findings are empirically sound and academically relevant.

From a conceptual standpoint, the novelty of this study lies in positioning naturalistic intelligence not as an individual learner attribute, but as an instructional design principle systematically integrated into the Problem Based Learning framework. This integration demonstrates that science learning which combines structured problem-solving with environment-based experiences can foster students' scientific literacy in a more comprehensive and balanced manner. Consequently, this study not only confirms the effectiveness of PBL, but also contributes new insights into how Problem Based Learning can be contextualized through the purposeful use of natural environments in elementary science education.

Based on the foregoing discussion, the findings provide a strong foundation for concluding that the implementation of a Problem Based Learning model grounded in naturalistic intelligence is closely associated with improvements in elementary school students' scientific literacy. These results also serve as a basis for articulating implications and recommendations, which are further elaborated in the conclusion section.

Conclusion

This study examined the application of a Naturalistic Intelligence Based Problem Based Learning model in elementary science instruction and its relation to students' scientific literacy. The findings, as interpreted in the discussion, indicate that learning designs which integrate structured problem-solving processes with direct engagement in natural environments are associated with improvements in scientific literacy across multiple dimensions. These results suggest that scientific literacy development in elementary education benefits from instructional approaches that emphasize contextual experience alongside systematic inquiry.

From a broader academic perspective, this study contributes to elementary science education by positioning naturalistic intelligence as a principle of instructional design within the Problem Based Learning framework, rather than as an individual learner trait alone. By aligning environmental interaction with problem-based inquiry, the study offers a refined approach to fostering functional scientific literacy that is grounded in students' lived experiences. While the conclusions are necessarily bounded by the study's design and context, the findings provide a foundation for further research employing comparative or longitudinal approaches to extend and deepen understanding of problem-based, context-rich science learning in primary education.

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