The European Journal of Humanities and Social Sciences 2025, No 3
ISSN 2414-2344

PREMIER Publishing
ppublishing.org

Section 6. Pedagogy

DOI:10.29013/EJHSS-25-3-30-38

PROJECT-BASED LEARNING IN SCIENCE ACTIVITIES: ENHANCING COGNITIVE DEVELOPMENT AND PROBLEM-SOLVING COMPETENCY IN PRESCHOOL CHILDREN

Pham Quang Tiep [1]

[1] VNU University of Education, Hanoi, Vietnam

Cite: *Pham Quang Tiep. (2025). Project-Based Learning in Science Activities: Enhancing Cognitive Development and Problem-Solving Competency in Preschool Children. European Journal of Humanities and Social Sciences 2025, No 3.* https://doi.org/10.29013/EJHSS-25-3-30-38

Abstract

Project-Based Learning (PBL) is becoming an effective approach in preschool education, especially in scientific discovery activities. This study aims to evaluate the impact of PBL on the cognitive development and problem-solving ability of preschool children through experiments with two groups of 5-6 year olds children: the experimental group (applying PBL) and the control group (traditional method). The results of the study showed that children in the experimental group had remarkable progress in scientific awareness (an average increase of 29.5%) and problem-solving ability (an average increase of 37.8%) compared to the control group. The PBL method not only helps children gain a deeper understanding of scientific phenomena but also encourages creative thinking and teamwork. From the above findings, the study proposes a process for designing science education projects suitable for preschool age, while emphasizing the role of teachers in guiding and creating a positive learning environment. This result suggests new directions in innovating preschool education methods in Vietnam to improve the quality of teaching and learning in a proactive, creative and practical manner.

Keywords: *Project education, Preschool science education, Cognitive development, Problem solving ability, Early education*

1. Introduction

In the context of modern education, preschool education is increasingly valued due to its key role in forming the foundation for children's comprehensive development. Scientific discovery activities at preschool level not only provide basic knowledge but also stimulate logical thinking, creativity and arouse the passion for learning in young children (*Nguyen Anh Tuyet, 2006*). According to Piaget's cognitive development theory, at preschool age, children have the ability to develop through direct exploration and processing of information from the environment. Therefore, organizing scientific activities in a way that encourages children's active participation is very important.

Project-based learning is emerging as an effective tool to promote children's active participation in hands-on, discovery-based learning activities (*Krajcik & Blumenfeld, 2006*). In contrast to traditional teaching methods where teachers play a central role, PBL allows children to solve learning situations themselves through age-appropriate projects. Children will learn to ask questions, investigate problems, and apply knowledge to find solutions, thereby developing critical thinking skills and problem-solving abilities (*Bell, 2015*). This approach transforms children from passive recipients of knowledge into active constructors of their own understanding through meaningful engagement with real-world problems.

In particular, in the context of preschool education in Vietnam, the PBL method has the potential to create positive changes in teaching and learning in a positive, proactive and creative direction. However, to fully exploit the potential of this method, further research is needed on its practical effectiveness, especially in scientific discovery activities (*Larmer & Mergendoller, 2015*). Although the PBL method has been widely applied in many countries and achieved certain successes in general and university education, its application in preschool education has not been fully studied. Some previous studies mainly focused on primary and secondary schools, where students have higher independent thinking ability and can handle complex tasks.

Preschool children have different cognitive and psychological characteristics, requiring appropriate adjustments in project design as well as the organization of learning activities. Studies on the effectiveness of PBL in preschool education often focus on the development of social or language skills, without deeply assessing the impact of this method on children's cognitive and scientific problem-solving abilities. Another important gap is the lack of empirical studies specifically measuring and comparing the effectiveness of PBL with traditional methods in science education activities. In Vietnam, although preschool education has made improvements in terms of curriculum and methods, the application of active teaching methods, especially PBL, is still limited and lacks consistency.

Furthermore, the integration of science education with project-based learning presents unique opportunities for developing children's scientific thinking from an early age. Early exposure to scientific concepts through hands-on exploration helps children develop inquiry skills, observation abilities, and logical reasoning that serve as building blocks for future academic success. The current educational landscape in Vietnam requires innovative approaches that can bridge the gap between theoretical knowledge and practical application, making PBL particularly relevant for contemporary educational needs.

Based on the above observations, the study focuses on the following two main questions:

How does the project-based education method affect the cognitive development of preschool children in scientific discovery activities?

Does this method improve preschool children's problem-solving ability compared to traditional teaching methods?

2. Literature review

2.1. Project-Based Learning and Science Education for Preschool Children

Project-Based Learning (PBL) has been developed since the early 20th century based on the theories of educators such as John Dewey (1897) and Kilpatrick (1918), who believed that learning should be linked to practical experiences and help learners solve real-life problems. According to Wang and Wang (2020), PBL is a teaching model in which learners engage in complex, open-ended projects designed based on real-world problems. The main features of PBL include focus on practical problems, learning through experience, increased opportunities for group collaboration, and focus on specific products as learning outcomes.

In a PBL environment, the teacher's role shifts from direct knowledge transmitter to facilitator and coach. Teachers need to pose open-ended questions, provide appropriate tools and materials, monitor progress while providing guidance when necessary. For preschool children, teachers must adjust project complexity to match cognitive abilities while creating stimulating learning environments and encouraging cooperation through games and group tasks (*Krajcik & Shin, 2015*).

Scientific discovery in preschool education is the process by which children learn and understand the natural world through observation, experimentation and direct experience. According to Eshach (2016), science education in preschool focuses on encouraging children to form habits of questioning, reasoning and observing phenomena. This contributes to developing basic skills including observation, questioning, logical thinking, and cooperation. Combining scientific discovery with project-based learning opens new opportunities for improving preschool education quality.

2.2. Theoretical Basis of Cognitive Development and Problem-Solving

According to Piaget's theory, children are active learners through interaction with the environment. Preschool children fall into the pre-operational stage (2-7 years old), characterized by intuitive thinking, focus on single aspects, and symbolic thinking. Piaget emphasized that preschool children should learn through hands-on activities such as play, experiments, and exploration of the natural environment to develop understanding of cause-and-effect relationships.

Vygotsky's theory of the Zone of Proximal Development (ZPD) emphasizes that children's cognitive development is driven by social interactions. The ZPD is the gap between what a child can do independently and what they can do with support from others (*Han et al., 2015*). Effective learning occurs when teachers design tasks within the child's ZPD, providing scaffolding through hints, questions, or resources, then gradually reducing support as children become more proficient.

Problem-solving ability in preschool children develops through practical activities such as science experiments, construction games, or group projects. According to Savery (2017), problem-solving involves using cognitive skills such as analysis, reasoning and planning to find solutions. Research by Nguyen Thi My Loc (2011) showed that children participating in project-based education activities developed problem-solving and creative thinking skills better than those taught by traditional methods. Combining principles from Piaget and Vygotsky's theories can create an optimal learning environment for children's overall development.

3. Research methods

3.1. Theoretical Research Method

Document analysis was conducted to collect and analyze domestic and foreign scientific documents related to preschool education, project-based learning (PBL) method, and theories on children's cognitive development. The research team systematically reviewed literature from multiple databases including educational journals, conference proceedings, and academic publications spanning from 2000 to 2024. The fundamental theories of Piaget and Vygotsky were synthesized to explain the cognitive development and problem-solving abilities of children in the context of scientific discovery activities.

Theoretical synthesis involved analyzing and integrating key concepts from constructivist learning theory, social learning theory, and contemporary research on early childhood education. The research team conducted comparative analysis between different teaching methodologies, particularly focusing on the distinctions between traditional teacher-centered approaches and modern student-centered pedagogical frameworks. This comprehensive literature review provided the theoretical foundation for developing the experimental design and research hypotheses.

3.2. Practical Research Methods

The empirical research methodology employed a mixed-methods approach combining quantitative experimental design with qualitative observational techniques. Scientific observation was conducted to monitor children's participation in exploration and learning activities, recording specific criteria including the number of questions asked during project implementation, level of proactive participation in group tasks, ability to cooperate and share ideas with peers, and progress in recording and reporting results. Trained observers used structured observation sheets to ensure consistency and reliability in data collection.

The experimental design followed a pre-test and post-test control group model with two distinct groups: an experimental group consisting of 24 children who participated in project-based educational activities using the PBL methodology, and a control group of 22 children who studied according to traditional teaching methods primarily involving teacher lectures and image-based demonstrations. Random assignment was used to ensure group equivalence and minimize selection bias.

Data collection instruments included standardized cognitive assessment tests designed specifically for preschool children, behavioral observation protocols validated for early childhood educational settings, and project product evaluation rubrics developed based on age-appropriate learning objectives. The cognitive measures assessed children's ability to remember basic scientific concepts such as plant growth cycles and factors affecting plant development, while problem-solving ability measures evaluated children's capacity to propose solutions to real-world scientific situations.

Assessment scales utilized a 100-point scoring system with clear criteria for evaluation. Behavioral observation sheets documented children's interactions during group activities, and project products such as plant life cycle diagrams were assessed using predetermined rubrics. Inter-rater reliability was established through training sessions for all evaluators, ensuring consistent application of assessment criteria across all participants.

The experimental process was carefully structured to maintain scientific rigor while accommodating the developmental needs of preschool children. Pre-experimental preparations included obtaining necessary permissions, briefing teachers and staff, and establishing baseline measurements for all participants. During the experimental phase, detailed protocols ensured consistent implementation of both PBL and traditional teaching approaches across the designated timeframe.

4. Results

4.1. Science Education Project Design Process

The design of science education projects for preschool children is fundamentally based on creating authentic learning experiences that connect to real-life situations while stimulating children's natural curiosity and exploration abilities. The comprehensive design process incorporates principles from the Project-Based Learning methodology, aiming to simultaneously develop children's scientific awareness and problem-solving capabilities through engaging, age-appropriate challenges that promote both individual growth and collaborative learning.

The project design process encompasses five systematically structured main steps, each carefully crafted to ensure that learning activities effectively encourage children's natural tendency to explore while providing ample opportunities to practice essential skills through direct experiential learning and meaningful teamwork interactions.

Step 1: Determine project goals and learning objectives - Project goals are meticulously determined based on the established preschool curriculum standards and the specific developmental needs of children within the target age group. The primary objectives consistently focus on helping children develop foundational understanding of basic scientific concepts while simultaneously cultivating essential thinking skills including systematic observation, analytical reasoning, logical explanation, and evidence-based inference making. Additional goals include fostering curiosity, encouraging scientific questioning, and developing communication skills through peer interaction and result presentation.

Step 2: Choose appropriate project topics - Project topics must be carefully selected to ensure they are familiar to children's everyday experiences, genuinely attractive to their natural interests, and appropriately matched to their current cognitive abilities and developmental stage. Topics are strategically chosen based on familiar natural phenomena or common problems that children frequently encounter in their daily environmental interactions. Potential topics that have proven particularly effective include the fascinating process of plant growth and development, the intriguing physical transformation of ice melting under different conditions, the cyclical process of evaporation and precipitation leading to rain formation, and the interaction between light sources and shadow creation.

Step 3: Develop comprehensive learning activities and tasks - Each project is systematically divided into specific, sequential activities that build upon each other, including structured observation periods, hands-on experimentation phases, creative diagram drawing sessions, collaborative group discussion opportunities, and formal presentation of results to peers and teachers. The tasks are intentionally designed to encourage children's active participation while stimulating their natural tendency to ask questions and seek answers through practical experiences and peer interaction. For example, a typical plant growth project might include: Activity 1 where children plant seeds and establish monitoring routines for plant growth observation; Activity 2 involving systematic observation and recording of differences between plants receiving regular watering versus those without adequate water supply; Activity 3 focusing on creating detailed diagrams of plant life cycles while engaging in group discussions about various factors that influence plant growth and development.

Step 4: Develop detailed project planning and organization - Projects are systematically divided into specific implementation stages with clearly defined timelines and milestone markers. Comprehensive planning includes detailed scheduling for each individual activity, strategic assignment of age-appropriate roles to children such as plant care teams, observation recording groups, and data collection teams, and careful selection of appropriate materials and tools including planting containers, various seed types, observation notebooks, and recording boards. Planning also incorporates flexibility to accommodate children's varying developmental paces and interests while maintaining project coherence and learning objectives.

Step 5: Develop comprehensive assessment tools and evaluation methods - Assessment strategies incorporate multiple evaluation approaches including standardized cognitive tests designed for preschool age groups, structured behavioral observation sheets for documenting learning processes, and systematic project product assessments focusing on tangible outcomes such as completed plant life cycle diagrams created by children. The evaluation methodology employs both quantitative measures through standardized testing and qualitative approaches through systematic observation, individual child interviews, and detailed analysis of project products and learning artifacts.

4.2. Project Implementation Example: "The Growth of Plants"

Project Overview and Objectives The "Growth of Plants" project was specifically designed for children aged 4-5 years with multiple interconnected learning objectives. Primary goals included helping children understand and identify the sequential stages of plant development from initial seed germination through mature plant formation, recognizing and explaining the essential elements necessary for healthy plant growth including soil composition, adequate water supply, sufficient light exposure, and proper air circulation, and developing fundamental scientific skills including systematic observation, accurate note-taking, and effective teamwork collaboration.

Detailed Activity Structure The project was organized into five progressive phases, each building upon previous learning while introducing new concepts and challenges. Phase 1, the start-up phase, involved children observing and comparing different types of seeds, with the specific goal of enabling children to distinguish between various seed types based on observable physical characteristics such as shape, size, color, and texture. Phase 2, the planting phase, engaged children in hands-on seed planting in prepared soil while establishing daily growth monitoring routines, helping children understand that water and soil provide necessary nutrients for plant germination and early development.

Phase 3 focused on observing differences through controlled experimentation, where children conducted comparative studies between plants receiving regular watering and care versus plants deliberately deprived of water, enabling children to understand that plants require consistent water supply and adequate light exposure for optimal growth and development. Phase 4 involved creating comprehensive life cycle diagrams where children drew detailed illustrations of plant development stages based on their direct observations, helping children describe and explain the complete growth cycle of plants from initial seed stage through mature plant development. Phase 5 culminated in group discussions where children collaboratively analyzed their observation results and presented findings to the class, developing essential presentation skills and teamwork abilities.

Expected Learning Outcomes and Products Children were expected to complete detailed plant life cycle diagrams accurately depicting all growth stages, demonstrate ability to explain various factors affecting plant growth and development, and successfully present experimental results while drawing logical conclusions through collaborative group discussion. Assessment focused on both individual understanding and collaborative learning skills.

4.3. Experimental Organization and Results

4.3.1. Detailed Experimental Description

Experimental Purpose and Rationale The experiment was designed with multiple interconnected objectives including evaluating the comparative effectiveness of PBL methodology versus traditional teaching approaches in developing cognitive abilities and problem-solving skills among preschool children, determining the extent of children's active engagement and participation when involved in project-based scientific discovery activities, and providing evidence-based practical recommendations for preschool educators in organizing effective science education activities that promote both individual and collaborative learning.

Participant Selection and Characteristics The experiment was conducted with 46 carefully selected children aged 5-6 years old, representing a developmentally appropriate sample for preschool education research. Participants were systematically divided into two comparable groups: an experimental group consisting of 24 children who engaged in project-based learning activities, and a control group of 22 children who received instruction through traditional teaching methods. Participant selection ensured demographic balance and equivalent baseline abilities across both groups.

Experimental Timeline and Setting The experimental period extended over 2 weeks, from December 9 to December 20, 2024, providing sufficient time for meaningful learning experiences while maintaining children's attention and engagement. The experimental location was a well-established kindergarten in Hanoi City, chosen for its representative characteristics of urban preschool educational settings and its capacity to accommodate the research requirements.

Experimental Content and Implementation Both groups explored the topic of plant growth, but through distinctly different pedagogical approaches. The experimental group participated in the comprehensive project "Growth of Plants" where children actively planted seeds, established daily monitoring routines for plant growth observation, systematically recorded developmental changes and growth patterns, and engaged in collaborative discussions about factors necessary for optimal plant growth and development. Meanwhile, the control group learned using traditional instructional methods, primarily observing static illustrations and participating in teacher-led demonstrations without hands-on experimentation or collaborative investigation opportunities.

4.3.2. Comprehensive Experimental Results

Cognitive Development Outcomes

Table 1. *Average scores of cognitive test before and after the experiment*

Group	N	Pre-test Average Score	Post-test Average Score	Increase	Rate of increase	Standard Deviation (SD)	T-test (p-value)
Experimental group	24	65.4 ± 5.3	84.7 ± 4.8	+19.3	+29.5%	5.3	$p < 0.01$
Control group	22	64.7 ± 4.9	73.1 ± 5.2	+8.4	+13%	5.1	$p < 0.01$

The experimental results demonstrate that the experimental group achieved significantly superior cognitive growth with an increase of +19.3 points representing a substantial +29.5% improvement compared to the control group's more modest increase of +8.4 points equivalent to +13% growth. The low standard deviation in the experimental group (SD = 5.3) indicates consistent improvement across participants, suggesting that most children experienced significant cognitive enhancement. The T-test results confirmed statistical significance ($p < 0.01$), providing strong evidence that the PBL method effectively improves children's cognitive development compared to traditional teaching approaches.

Through systematic direct observation during the experimental period, researchers documented that children in the experimental group frequently generated open-ended questions such as "What would happen if the plants had no light?" or "Why does this plant grow faster than that plant?" demonstrating enhanced curiosity and scientific thinking. In contrast, children in the control group primarily focused on recalling information from teacher presentations without developing independent inquiry skills or demonstrating significant open-ended thinking patterns.

Problem-solving Ability Development

Children in the experimental group demonstrated remarkable growth in problem-solving capabilities with an increase of +22.7 points representing a substantial +37.8% improvement compared to the control group's increase of +9.2 points equivalent to +15% growth. ANOVA test results confirmed statistical significance ($p < 0.01$), providing strong evidence for the effectiveness of project-based learning in developing problem-solving skills. Children in the experimental group consistently demonstrated flexibility and creativity in identifying multiple solutions to scientific challenges, frequently testing various approaches and engaging in peer discussions about results and implications.

For example, during ice melting experiments, children in the experimental group not only implemented suggested solutions but also independently proposed additional creative approaches such as using warm water, direct sunlight exposure, or air circulation to accelerate the melting process. Meanwhile, although control group children showed some improvement, they primarily followed teacher instructions and demonstrated limited opportunities for creative exploration or independent solution development, resulting in significantly lower growth rates compared to the experimental group.

Qualitative Observations and Project Product Analysis

Children in the experimental group successfully created detailed diagrams accurately depicting plant growth stages and provided clear explanations of the roles of essential factors such as water supply and light exposure in plant development. They demonstrated confidence in presenting experimental results to classmates and exhibited strong cooperation and information-sharing abilities during group activities. Additionally, these children frequently engaged in collaborative testing of different solutions and maintained ongoing discussions about results with peers, demonstrating enhanced critical thinking and collaborative problem-solving skills.

In contrast, children in the control group were unable to independently create comprehensive growth diagrams and relied heavily on teacher-provided visual materials and guidance. They demonstrated limited independent thinking and rarely proposed original hypotheses or creative solutions, typically waiting for explicit teacher direction rather than taking initiative in their learning process.

5. Conclusion and discussion

The experimental results provide compelling evidence that Project-Based Learning (PBL) significantly impacts both cognitive development and problem-solving abilities of preschool children. The experimental group achieved remarkable cognitive growth of +29.5% and problem-solving improvement of +37.8%, substantially exceeding the control group's gains of +13% and +15% respectively. These findings demonstrate the superior effectiveness of active, hands-on learning approaches compared to traditional passive instruction methods.

These results align consistently with theoretical foundations established by Piaget and Vygotsky's developmental theories. According to Piaget's theory, preschool children in the pre-operational stage achieve optimal learning through practical activities and direct experiential engagement. The PBL methodology successfully created such environments, enabling children to learn through meaningful interaction with scientific phenomena. The superior cognitive growth can be explained through Vygotsky's Zone of Proximal Development (ZPD) theory, where children receiving appropriate guidance transcend their current cognitive limitations and achieve deeper conceptual understanding.

The research findings have profound practical implications for innovating teaching methodologies in kindergarten settings. The PBL approach demonstrates that young children not only memorize scientific concepts but develop deep conceptual understanding and practical application skills. Children actively explored scientific phenomena, developed critical thinking abilities and creative problem-solving skills essential for lifelong learning success. Furthermore, PBL significantly promotes collaborative teamwork skills, as children regularly engage in peer discussions, share ideas, and learn from each other through constructive dialogue.

Preschool educational institutions should systematically integrate project-based learning approaches into their established curricula, particularly in subjects involving scientific inquiry and critical thinking development. Teachers require comprehensive professional development training to effectively design age-appropriate projects that meaningfully engage children in questioning processes and collaborative problem-solving activities. Educational administrators should invest in necessary materials, equipment, and physical spaces that support hands-on learning experiences while providing ongoing support for teacher development and curriculum innovation.

Despite significant positive findings, this study acknowledges important limitations. The research was conducted with a relatively small sample size of 46 children at a single location, potentially limiting generalizability across diverse contexts. The experimental duration of only 2 weeks was insufficient for measuring long-term retention and sustainable development. Various external factors including teacher experience, parental support, and learning environment conditions may have affected outcomes but were not systematically controlled.

Future research should address these limitations through larger-scale studies incorporating diverse participant populations across multiple geographical regions to ensure broader generalizability. Longitudinal research extending over entire academic years would provide valuable insights into sustainability and long-term developmental impacts of PBL approaches. Additionally, comprehensive studies should expand assessment beyond cognitive and problem-solving domains to include social-emotional development, communication skills, and creativity. Research investigating the integration of modern educational technologies with traditional PBL approaches could provide valuable insights for contemporary educational practice.

References

Bell, S. (2015). Project-based learning for the 21st century: Skills for the future. *The Clearing House: A Journal of Educational Strategies, Issues and Ideas*, – 88(2). – P. 75–79.

Dewey, J. (1897). *My pedagogic creed*. E. L. Kellogg & Co.

Eshach, H., & Fried, M.N. (2016). Should science be taught in early childhood? *Journal of Science Education and Technology*, – 25(1). – P. 1-18.

Han, S., Capraro, R., & Capraro, M.M. (2015). How science, technology, engineering, and mathematics (STEM) project-based learning affects high, middle, and low achievements differently. *International Journal of Science and Mathematics Education*, – 13(5). – P. 1089–1113.

Kilpatrick, W.H. (1918). *The project method: The use of the purposeful act in the educative process*. Teachers College, Columbia University.

Krajcik, J.S., & Blumenfeld, P.C. (2006). Project-based learning. In R. K. Sawyer (Ed.), *The Cambridge handbook of the learning sciences* (pp. 317–334). Cambridge University Press.

Krajcik, J. S., & Shin, N. (2015). Project-based learning. In R. K. Sawyer (Ed.), *The Cambridge handbook of the learning sciences* (2nd ed., pp. 275–295). Cambridge University Press.

Larmer, J., & Mergendoller, J. R. (2015). *Gold standard PBL: Essential project design elements*. Buck Institute for Education.

Nguyen Anh Tuyet. (2006). *Preschool education textbook*. Hanoi National University of Education Publishing House.

Nguyen Thi My Loc, & Nguyen Thi Minh Hang. (2011). Developing problem-solving skills for preschool students through experiential activities. *Journal of Education and Development*, – 21. – P. 54-58.

Savery, J. R. (2017). Overview of problem-based learning: Definitions and distinctions. *The Interdisciplinary Journal of Problem-Based Learning*, – 11(2). – P. 9-22.

submitted 28.04.2025;
accepted for publication 12.05.2025;
published 30.06.2025

Contact: tiep@vnu.edu.vn