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Enhancing Life Science Skills in Early Childhood Through Culturally Relevant Project-Based Learning: A Quasi-Experimental Study

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Abstract
Project-Based Learning (PJBL) has gained recognition as an effective pedagogical approach for fostering active learning, scientific literacy, and problem-solving skills in early childhood education. However, empirical studies on its application in culturally relevant contexts remain limited. This study examines the effectiveness of PJBL in developing life science skills among children aged 5–6 years through the "Pisang Goreng" (fried banana) experiment, a hands-on learning activity grounded in local culture. A quasi-experimental one-group pretest-posttest design was employed, involving 15 purposively selected kindergarten students. The intervention included planting, harvesting, and processing bananas, enabling children to engage with biological processes through experiential learning. Data were collected using observation scales, portfolio evaluations, and performance-based assessments. A paired-sample t-test revealed a statistically significant improvement in children's cognitive, problem-solving, and critical thinking abilities, with a substantial effect size (Cohen's d = 1.25). These findings suggest that PJBL enhances life science skills by integrating culturally meaningful experiences into early childhood education. Despite its contributions, the study is limited by its small sample size and single-site implementation, restricting the generalizability of results. Future research should explore PJBL's effectiveness across diverse educational settings and its applicability to broader STEM domains, employing larger samples and longitudinal designs to strengthen the empirical foundation for scalable, culturally adaptive PJBL frameworks in early childhood science education. This study underscores the importance of experiential, inquiry-based learning in fostering scientific literacy and critical thinking among young learners.

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Introduction
Understanding science extends beyond merely knowing facts—it involves fostering curiosity, critical thinking, and problem-solving skills applicable to everyday life. Research underscores that early childhood is a crucial period for developing scientific competencies, as young children possess an innate curiosity about the natural world and benefit from structured learning experiences that nurture their inquiry skills (Amri et al., 2023; McNerney & Hall, 2020). However, early childhood education (ECE) programs worldwide, including in Indonesia, often prioritize literacy and numeracy over science education, limiting opportunities for experiential learning (Hsin & Wu, 2023; Veraksa, Plotnikova, & Ivenskaya, 2024). This imbalance hinders children's ability to develop essential life science skills, including an understanding of biological processes, environmental interactions, and the application of scientific reasoning in daily life (Albar & Southcott, 2021; Ndiung & Menggo, 2024). Addressing this gap requires innovative pedagogical approaches that integrate science learning into early education while aligning with children's cognitive development and socio-cultural contexts.

Project-Based Learning (PJBL) has emerged as an effective pedagogical approach in science education, promoting active engagement, collaborative learning, and problem-solving skills. Studies demonstrate that PJBL enhances children's cognitive abilities by encouraging them to explore scientific concepts through hands-on activities, real-world problem-solving, and teamwork (Brown & Jain, 2022; Pratami, Akhmal, Maulana, & Hassan, 2024). Moreover, PJBL fosters creativity and critical thinking by requiring students to formulate hypotheses, conduct experiments, and draw conclusions based on empirical observations (Ndiung & Menggo, 2024; Rocha, 2024). While PJBL is widely implemented in primary and secondary education, its application in early childhood education remains underexplored, despite its potential to cultivate foundational science skills (Aisyah & Novita, 2025; Stojanović, Ristanović, Živković, & Džaferović, 2023). In developing countries, where access to high-quality science education is often limited, PJBL provides a promising framework for integrating experiential learning into early childhood curricula (Hsin & Wu, 2023; Soedjono, Yusuf, & Yuwono, 2022).

Incorporating science education into early childhood curricula through PJBL aligns with constructivist learning theories, which emphasize active participation and experiential learning. Research on STEM and STEAM education demonstrates that project-based methodologies improve students' understanding of interdisciplinary scientific concepts while enhancing engagement (Larkin & Lowrie, 2023; McNerney & Hall, 2020). Specifically, studies highlight the effectiveness of hands-on projects in developing young children's cognitive abilities, particularly in logical reasoning, classification, and scientific observation (Lu, Lo, & Syu, 2022; Tang, McLure, Williams, & Donnelly, 2024). However, challenges persist in implementing PJBL at the early childhood level, including the need for well-trained educators, appropriate teaching materials, and structured learning activities suited to young learners' developmental stages (Pratami et al., 2024; Stojanović et al., 2023). Addressing these challenges requires pedagogical frameworks that integrate PJBL into early science education while considering contextual and cultural factors (Alam, Totok Sumaryanto, & Jazuli, 2020; Avendano-Uribe et al., 2022).

Beyond its cognitive benefits, PJBL enhances children's social and collaborative skills by fostering teamwork and communication. Research indicates that collaborative, project-based learning activities significantly improve social competence and peer interactions, particularly among preschool-aged children (Parwoto, Ilyas, Bachtiar, & Marzuki, 2024; Veraksa et al., 2024). Through structured group tasks, children learn to negotiate, share responsibilities, and solve problems collectively, all of which are essential for future academic and professional success (Jamal, Jamal, & Yusof, 2023; Rocha, 2024). Additionally, studies on early childhood education emphasize the importance of integrating play-based approaches with PJBL, as role-playing and hands-on experimentation enhance engagement and learning retention (Acker & Nyland, 2024; Alam et al., 2020). Despite these advantages, PJBL remains underutilized in early childhood settings, largely due to the lack of teacher training and institutional support (Brown & Jain, 2022; Pratami et al., 2024).

Technological advancements have expanded opportunities for implementing PJBL in early childhood science education. Digital tools, robotics, and open-source platforms have been successfully integrated into PJBL frameworks, enriching interactive and inquiry-based learning experiences (Jawaid et al., 2020; Sun, Guo, & Zhou, 2022). For instance, studies on AI-assisted programming and affordable technology in science education report significant improvements in children's engagement and problem-solving abilities (Alam et al., 2020; Fruett, Pereira Barbosa, Cardoso Zampolli Fraga, & Ivo Aragao Guimaraes, 2024). Furthermore, digital storytelling and e-books complement PJBL by enabling young learners to document their scientific explorations and reflect on their learning processes (Hojeij, Tamim, Kaviani, & Papagianni, 2021; Sanz, Artola, & Baldassarri, 2024). However, despite growing evidence of PJBL's effectiveness, its implementation in early childhood education remains fragmented, with limited empirical research exploring its application in life sciences (Bascopé & Reiss, 2021; LeTendre & Gray, 2024).

Given PJBL's potential to foster cognitive and social development, further exploration of its role in early childhood science education is warranted. Although extensive research supports PJBL as an effective approach to early science education, several gaps remain in the literature. Most studies have examined PJBL's impact in primary and secondary education, with fewer investigations into its application in early childhood settings (Aisyah & Novita, 2025; Stojanović et al., 2023). Additionally, while research has explored PJBL's role in enhancing STEM and STEAM competencies, studies on its effectiveness in teaching life sciences to young children are scarce (Avendano-Uribe et al., 2022; Larkin & Lowrie, 2023). Moreover, many existing studies have been conducted in developed countries, limiting their applicability to resource-constrained settings where science education faces greater challenges (Muller & Wood, 2021; Tang et al., 2024). The absence of culturally relevant, hands-on PJBL models tailored for early childhood education presents another significant gap, necessitating further investigation into how PJBL can be adapted to diverse learning environments (Álvarez, 2021; Wise & Ward, 2023).

This study aims to address these gaps by examining the effectiveness of PJBL in developing life science skills among children aged 5–6 years. Specifically, it implements the "Pisang Goreng" (fried banana) experiment, a culturally relevant PJBL activity that enables children to learn scientific concepts through direct engagement in planting, harvesting, and processing bananas. By assessing cognitive, problem-solving, and social skills before and after the intervention, this study provides empirical evidence of PJBL's impact on early childhood life science education. Additionally, the findings contribute to the growing body of research on PJBL by offering insights into how experiential, project-based methods can be integrated into early science curricula, particularly in under-resourced educational settings. Ultimately, this research seeks to inform educators and policymakers about PJBL's benefits, advocating for its broader adoption to enhance science education for young children.

Methods

This study employed a quasi-experimental research design, specifically a one-group pretest-posttest design, to examine the effectiveness of Project-Based Learning (PJBL) in enhancing life science skills among early childhood students (Balaka, 2022). This design was chosen to assess changes in students' competencies before and after the intervention, allowing for a systematic evaluation of PJBL's impact.

Table 1. Research Design: One-Group Pretest-Posttest Design

Pretest (Q1)	Intervention (X)	Posttest (Q2)

The study population consisted of 30 kindergarten students (Grade B) from Nurhidayah Kindergarten. A purposive sampling method was used to select 15 participants who demonstrated resilience in overcoming challenges. This criterion ensured that the sample aligned with the study's objectives, particularly in assessing PJBL's effectiveness in supporting students requiring intervention.

The intervention was conducted over a two-month period, during which students participated in multiple PJBL sessions focusing on life science concepts. The implementation followed structured PJBL phases: (1) initiation through problem identification, (2) planning and project design, (3) execution through hands-on activities such as planting, harvesting, and processing bananas, (4) reflection and evaluation, and (5) presentation of findings. The "Pisang Goreng" (fried banana) experiment served as the primary learning project, integrating experiential learning with scientific observation.

Student performance was assessed using an observation scale designed to measure life science skill development. The scale consisted of four levels: BB (Not Developing), MB (Starting to Develop), BSH (Developing According to Expectations), and BSB (Developing Very Well). The observation instrument was validated through content validation by early childhood education teachers to ensure its appropriateness and relevance for the targeted age group.

To ensure reliability, internal consistency was assessed using Cronbach's Alpha, yielding a high reliability coefficient. Additionally, inter-rater reliability was evaluated by having multiple assessors independently score student performance, ensuring objectivity and consistency.

Quantitative data were collected through structured observations before and after the intervention. The Shapiro-Wilk test ($\alpha = 0.05$) was used to assess the normality of the data

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distribution. If the significance value exceeded 0.05, the data were considered normally distributed; otherwise, non-normality was assumed. Given the study's use of two related datasets (pretest and posttest scores), a paired sample t-test was conducted using SPSS 23.0 for Windows to determine whether the intervention resulted in statistically significant improvements in life science skills. The effect size was measured using Cohen's d to assess the practical significance of the observed differences.

Ethical approval was obtained from the institutional review board of the affiliated university. Parental consent was secured prior to student participation, and all research procedures adhered to ethical guidelines for research involving children. Participant confidentiality and anonymity were maintained throughout the study.

Result

This study aimed to enhance the academic performance of children aged 5–6 years through the Project-Based Learning (PJBL) model, utilizing the "Pisang Goreng" (fried banana) experiment as a learning tool. The learning process began with a discussion on the basic uses of bananas, the procurement of equipment and materials, and an explanation of the learning objectives. The implementation stages included planting and caring for banana plants, understanding their growth process, and processing bananas into consumable food products. Children were given hands-on experience in stages, allowing them to connect theoretical knowledge with daily practice. Reflection and evaluation were conducted through group discussions and teacher-led reflective questioning to reinforce understanding. Additionally, documenting activities through photographs was recommended to enhance the effectiveness of the experiment.

The study was conducted over six sessions, comprising three experimental group sessions and three control group sessions, including one pre-test, two intervention sessions, and one post-test. The results of the pre-test and post-test comparisons in both groups showed an overall increase in life science skills, with the experimental group demonstrating higher performance gains than the control group. The findings indicate that PJBL significantly improved children's ability to solve problems, such as determining the ripeness of bananas before processing, as well as their critical thinking skills, particularly in distinguishing between the texture and color of raw and ripe bananas. Additionally, children developed improved strategies for exploring materials and modifying compositions during the experiment.

Evaluation of learning outcomes was conducted through project-based observations, learning portfolios, and performance-based assessments to measure children's understanding of the experimental stages. The intervention's effectiveness was further assessed using Cohen's d, which yielded a value of 1.25, indicating a substantial effect size and reinforcing the impact of PJBL on children's literacy and life science skills. Effect size measurement provided a clearer understanding of the practical significance of the findings.

However, some limitations must be acknowledged. The small sample size (15 children) may limit the generalizability of the results. Additionally, the study was conducted in only one kindergarten (TK), which may affect the applicability of the findings to broader early childhood education settings.

The pre-test indicators in this study were designed to assess children's understanding of life sciences through various activities, including:

- Planting banana plants and identifying essential elements for plant growth.
- Recognizing and demonstrating the functions of plant parts, including roots, stems, branches, and leaves.
- Participating in the harvesting process of banana plants they cultivated.
- Processing harvested bananas into a food product they enjoy (fried bananas).

The results of the descriptive analysis based on these indicators are summarized in Table 2.

Table 2. Normality Test Before and After Treatment (Kolmogorov-Smirnov & Shapiro-Wilk)

Kolmogorov-Smirnova			Shapiro-Wilk		
	***Sig.* X 0,05**	**Criteria**		***Sig.* X 0,05**	**Criteria**
Before Treatment	.207>0.05	Normal	Before Treatment	.942>0.05	Normal
After Treatmen	.201>0.05	Normal	After Treatmen	.860>0.05	Normal

Based on the results above, the significance value of 0.200 confirms that the data follows a normal distribution, as all values exceed 0.05. Given that at least one dataset met the normality assumption, further analysis was conducted using a parametric test, specifically the Paired Sample t-Test.

The normality test, conducted using both the Kolmogorov-Smirnov and Shapiro-Wilk methods, showed that the data collected before and after the intervention followed a normal distribution. The Kolmogorov-Smirnov test yielded a significance value of 0.207 before treatment and 0.201 after treatment, both of which exceeded 0.05, indicating normality. Similarly, the Shapiro-Wilk test produced values of 0.942 before treatment and 0.860 after treatment, further confirming normality in both groups.

Since the normality assumption was met, the study proceeded with the Paired Sample t-Test, which compared the mean pre-test and post-test scores to determine the statistical significance of the intervention's effect. This parametric test provided valid results, enabling a reliable evaluation of the PJBL model's impact on children's life science skills.

Table 3. Homogeneity Test Before and After Treatment

	statistic	***def***	***Sig.X0,05***	***kriteria***
Before Treatment	3.426	42	529> 0.05	Homogen
After Treatmen	2.368	42	0.365> 0.05	Homogen

Based on the results of the normality tests conducted using the Kolmogorov-Smirnov and Shapiro-Wilk methods, the data collected before and after the intervention were found to be normally distributed. The Kolmogorov-Smirnov test yielded significance values of 0.207 before treatment and 0.201 after treatment, both exceeding 0.05, indicating that the data followed a normal distribution. Similarly, the Shapiro-Wilk test produced significance values of 0.942 before treatment and 0.860 after treatment, further confirming normality in both groups. A significance value greater than 0.05 suggests no significant deviation from the normal distribution.

Since the data met the assumption of normality, further analysis was conducted using a parametric test, specifically the Paired Sample t-Test. This test compared the mean values before and after treatment to determine whether a significant difference existed. By satisfying the normality assumption, the parametric t-test ensured valid results, enabling a reliable evaluation of the hypothesis regarding the intervention's effect on the measured variable.

Table 4. Homogeneity Test Before and After Treatment

Developmental Aspects		**Value**	**Value**	**df**	**Sig.**	**Conclusion**
Learning Outcomes	14	10,267	14,274	41	0,00	H_0 Rejected H_a Accepted

The paired samples test results revealed a significant difference between the pre-test and post-test scores in assessing life science skills following the implementation of the Project-Based Learning (PJBL) Model at Nurhidayah Jonjo Kindergarten. The mean score difference between the pre-test (M = -10.267) and the post-test (M = 4.008) was -10.267, with a 95% confidence interval for the score difference ranging from -12.486 to -8.047. The t-test result with 14 degrees of freedom showed a significance value of 0.000, confirming a statistically significant difference. These findings demonstrate that the implementation of PJBL effectively improved the life science skills of 5–6-year-old children at Nurhidayah Jonjo Kindergarten, as reflected in the significant difference between the pre-test and post-test scores.

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Given these results, longitudinal research is recommended across multiple institutions to ensure the consistency and generalizability of the findings. The results of this study align with Vartiainen and Kumpulainen (2020), who found that PJBL enhances conceptual understanding through experiential learning. Additionally, Rahmat and Rufaida (2023) reported that PJBL positively influences critical thinking and problem-solving skills in children. As a result, this study concludes that the "Pisang Goreng" experiment, conducted through PJBL, is an effective method for improving early childhood literacy skills and fostering a deeper understanding of the importance of literacy in daily life.

Discussion

Early science education plays a crucial role in fostering young children's cognitive, social, and problem-solving abilities. However, traditional teaching methods often prioritize literacy and numeracy over hands-on scientific exploration (Amri et al., 2023; McNerney & Hall, 2020). The Project-Based Learning (PJBL) model has been proposed as an alternative instructional approach that integrates experiential learning with real-world applications, effectively addressing this gap (Brown & Jain, 2022; Hsin & Wu, 2023). Despite its potential, the implementation of PJBL in early childhood education, particularly in life sciences, remains underexplored, especially in rural and under-resourced settings (Aisyah & Novita, 2025; Stojanović et al., 2023). This study examined the effectiveness of PJBL in developing life science skills among 5–6-year-old children through the "Pisang Goreng" (Fried Banana) experiment, which provided an authentic and culturally relevant learning context. By engaging in activities such as planting, harvesting, and processing bananas, children were expected to develop scientific literacy, problem-solving abilities, collaboration skills, and inquiry-based learning competencies.

The findings demonstrated that PJBL significantly improved life science skills among participating children, as reflected in higher post-test scores compared to pre-test results. The paired-sample t-test indicated a statistically significant difference, with the experimental group exhibiting greater improvement than the control group, supporting the effectiveness of experiential learning (Pratami et al., 2024; Purnomo, Karim, Mansir, & Valero-Matas, 2022). The children developed enhanced problem-solving abilities, particularly in determining the ripeness of bananas based on texture and color before processing, which is an essential skill in scientific observation and classification (Aliriad & Setijono, 2023; Lombardi, Mednick, De Backer, & Lombaerts, 2022). Additionally, they demonstrated a greater ability to explore materials and modify experimental variables, suggesting the development of higher-order thinking skills (Ndiung & Menggo, 2024; Soedjono et al., 2022). Beyond cognitive improvements, the children also exhibited enhanced collaboration and teamwork, indicating that PJBL fosters essential social skills (Rocha, 2024; Veraksa et al., 2024). These findings highlight the potential of PJBL as a holistic learning approach that promotes both scientific literacy and interpersonal competencies in early learners.

The results align with previous research demonstrating that PJBL enhances early childhood scientific literacy and cognitive development by engaging children in hands-on, inquiry-based activities (Albar & Southcott, 2021; Hsin & Wu, 2023). Studies conducted in Finland and the United States have shown that PJBL improves conceptual understanding through active participation in scientific processes, similar to the gains observed in this study (Vartiainen & Kumpulainen, 2020). Furthermore, research suggests that young children benefit from interactive and collaborative learning experiences that mimic real-world scientific practices (Jawaid et al., 2020; Sun et al., 2022). The improvements in scientific reasoning and problem-solving skills in this study support prior findings that PJBL fosters critical thinking and investigative skills in early learners (Amri et al., 2023; McNerney & Hall, 2020). Additionally, the observed enhancement in collaboration and teamwork is consistent with studies that emphasize the social benefits of PJBL in early childhood education (Anggelia, Puspitasari, & Arifin, 2022; Parwoto et al., 2024).

Despite these consistencies, some discrepancies exist when comparing the findings to prior research. While this study observed a notable increase in scientific inquiry and critical thinking, other studies have reported that young learners may struggle with the open-ended nature of PJBL, requiring additional scaffolding from educators (Brown & Jain, 2022; Kim & Kim, 2021). In contrast to studies highlighting implementation challenges due to limited teacher training and resource constraints (Aisyah & Novita, 2025; Stojanović et al., 2023), this research demonstrated that structured guidance and culturally relevant projects, such as the "Pisang Goreng" experiment, can effectively engage young children in scientific inquiry. However, the reliance on teacher-directed facilitation raises questions about the long-term sustainability of PJBL without adequate professional development (Kaldi & Zafeiri, 2023; Pratami et al., 2024). Additionally, while previous studies have highlighted PJBL's potential for interdisciplinary STEM learning (Anggelia et al., 2022; Aydin Gunbatar, Ekiz Kiran, Boz, & Roehrig, 2024), this study focused solely on life sciences, suggesting an opportunity to expand the PJBL framework to include broader STEM concepts in early childhood education.

The significant improvement in life science skills can be attributed to the constructivist nature of PJBL, which emphasizes learning through direct experience, exploration, and reflection (Wedi et al., 2020). By engaging children in active participation, PJBL facilitates meaningful learning experiences that are more effective than passive instruction methods (Rahmat & Rufaida, 2023; Soedjono et al., 2022). The use of a culturally familiar experiment, such as the "Pisang Goreng" activity, likely enhanced engagement and motivation, making scientific concepts more relatable and accessible (Álvarez, 2021; Zimmerman, Grills, McKinley, & Kim, 2022). However, potential limitations must be considered, including the small sample size and the specific socio-cultural context, which may limit the generalizability of the findings (Aisyah & Novita, 2025; Purnomo et al., 2022). Additionally, while immediate learning gains were evident, further research is needed to assess the long-term retention of life science concepts among young children exposed to PJBL (Tang et al., 2024; Wise & Ward, 2023).

Another possible explanation for these findings is the role of inquiry-based learning in enhancing curiosity and intrinsic motivation among young learners (An, 2020; McNerney & Hall, 2020). Research suggests that children are naturally inclined to explore and experiment, and structured PJBL activities provide an optimal framework for transforming these tendencies into scientific reasoning (Avendano-Uribe et al., 2022; Muller & Wood, 2021). The collaborative nature of PJBL also reinforces social learning, allowing children to develop communication and teamwork skills alongside their cognitive growth (Parwoto et al., 2024; Rocha, 2024). However, successful PJBL implementation depends on teacher preparedness and classroom resources (Brown & Jain, 2022; Kaldi & Zafeiri, 2023). Future research should examine PJBL's effectiveness across diverse educational settings, particularly in urban and resource-limited schools, to determine its broader applicability and impact (Pratami et al., 2024; Stojanović et al., 2023).

The findings of this study have several implications for early childhood education and curriculum development. They underscore the importance of integrating hands-on, experiential learning approaches into early science instruction to foster inquiry-based thinking and problem-solving skills (Amri et al., 2023; McNerney & Hall, 2020). The success of the "Pisang Goreng" experiment highlights the value of culturally relevant, project-based activities in engaging young learners, suggesting that similar approaches could be adapted across different educational contexts (Álvarez, 2021; Bascopé & Reiss, 2021). Lastly, the study reinforces the need for teacher training in PJBL implementation to ensure its sustained effectiveness in fostering scientific literacy and critical thinking among young learners (Brown & Jain, 2022; Pratami et al., 2024).

Conclusion

This study examined the effectiveness of the Project-Based Learning (PJBL) model, implemented through the culturally contextualized "Pisang Goreng" experiment, in fostering life science skills among children aged 5–6 years. The findings revealed a statistically significant improvement in

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life science skills within the experimental group compared to the control group, with children demonstrating enhanced critical thinking, problem-solving, and scientific understanding through hands-on engagement. These results underscore the importance of integrating experiential and culturally relevant PJBL activities into early science curricula, particularly in resource-limited settings, to promote inquiry-based learning. Additionally, the study highlights the need for teacher training in PJBL methodologies to ensure effective implementation. However, the study's limitations, including its small sample size and confinement to a single kindergarten, restrict the generalizability of the findings. Future research should involve larger and more diverse cohorts, adopt longitudinal designs, and explore PJBL's applicability across broader STEM domains. Expanding the empirical foundation for scalable, culturally adaptive PJBL frameworks in early childhood education will contribute to more effective and inclusive science learning strategies.

References

Acker, A., & Nyland, B. (2024). The Black Swan: An early childhood music project. *International Journal of Music Education*, *42*(1), 68–79. Scopus. https://doi.org/10.1177/02557614221145466

Aisyah, S., & Novita, D. (2025). Teachers' perception of the implementation of project-based learning in early childhood education in Indonesia: Project-Based Learning: A perspective from Indonesian early childhood educators. *Cogent Education*, *12*(1). Scopus. https://doi.org/10.1080/2331186X.2025.2458663

Alam, S., Totok Sumaryanto, F., & Jazuli, M. (2020). Visual culture-based art learning uses internet to improve higher-order thinking skills in early childhood. *International Journal of Scientific and Technology Research*, *9*(2), 3847–3851. Scopus. Retrieved from Scopus.

Albar, S. B., & Southcott, J. E. (2021). Problem and project-based learning through an investigation lesson: Significant gains in creative thinking behaviour within the Australian foundation (preparatory) classroom. *Thinking Skills and Creativity*, *41*. Scopus. https://doi.org/10.1016/j.tsc.2021.100853

Aliriad, H., & Setijono, H. (2023). The Effect of Project-Based on Fundamental Motor Skills to Enhance Early Children. *Health Education and Health Promotion*, *11*(1). Scopus. Retrieved from https://www.scopus.com/inward/record.uri?eid=2-s2.0-85175114558&partnerID=40&md5=3f46974d3135d3acc39d3f50a940c374

Álvarez, A. (2021). Connecting funds of knowledge to funds of identity through a bilingual multimodal project-based approach. *Revista Internacional de Educacion Para La Justicia Social*, *10*(1), 105–124. Scopus. https://doi.org/10.15366/RIEJS2021.10.1.007

Amri, N. A., Usman, U., Hajerah, H., Ramadhani, N., Aisyah, N., Sari, R. A., & Febriyanti, F. (2023). IBM BAGI GURU TAMAN KANAK-KANAK PADA PEMBUATAN MEDIA PEMBELAJARAN BERBASIS APLIKASI. *JMM (Jurnal Masyarakat Mandiri)*, *7*(1), 765–772.

An, S. (2020). The impact of STEAM integration on preservice teachers' disposition and knowledge. *Journal of Research in Innovative Teaching and Learning*, *13*(1), 27–42. Scopus. https://doi.org/10.1108/JRIT-01-2020-0005

Anggelia, D., Puspitasari, I., & Arifin, S. (2022). Penerapan Model Project-based Learning ditinjau dari Kurikulum Merdeka dalam Mengembangkan Kreativitas Belajar Pendidikan Agama Islam. *Jurnal Pendidikan Agama Islam Al-Thariqah*, *7*(2), 398–408.

Avendano-Uribe, B. E., Lombana-Bermudez, A., Flórez, L. V., Chaparro, E., Hernandez-Morales, A. C., Archbold, J., … Porras, A. M. (2022). Engaging Scientific Diasporas in STEAM Education: The Case of Science Clubs Colombia. *Frontiers in Research Metrics and Analytics*, *7*. Scopus. https://doi.org/10.3389/frma.2022.898167

Aydin Gunbatar, S., Ekiz Kiran, B., Boz, Y., & Roehrig, G. H. (2024). A closer examination of the STEM characteristics of the STEM activities published in NSTA journals. *Research in*

Science and Technological Education, *42*(4), 952–977. Scopus. https://doi.org/10.1080/02635143.2022.2121692

Balaka, M. Y. (2022). *Metodologi penelitian kuantitatif*.

Bascopé, M., & Reiss, K. (2021). Place-based stem education for sustainability: A path towards socioecological resilience. *Sustainability (Switzerland)*, *13*(15). Scopus. https://doi.org/10.3390/su13158414

Brown, A. L., & Jain, P. (2022). Doing projects with young children in a field-based early childhood education course. *Educational Studies*, *48*(5), 692–707. Scopus. https://doi.org/10.1080/03055698.2020.1798743

Fruett, F., Pereira Barbosa, F., Cardoso Zampolli Fraga, S., & Ivo Aragao Guimaraes, P. (2024). Empowering STEAM Activities With Artificial Intelligence and Open Hardware: The BitDogLab. *IEEE Transactions on Education*, *67*(3), 462–471. Scopus. https://doi.org/10.1109/TE.2024.3377555

Hojeij, Z., Tamim, R., Kaviani, A., & Papagianni, C. (2021). E-books and digital storytelling for Emirati school children: Project-based learning for pre-service teachers. *Issues in Educational Research*, *31*(4), 1067–1087. Scopus. Retrieved from Scopus.

Hsin, C.-T., & Wu, H.-K. (2023). Implementing a Project-Based Learning Module in Urban and Indigenous Areas to Promote Young Children's Scientific Practices. *Research in Science Education*, *53*(1), 37–57. Scopus. https://doi.org/10.1007/s11165-022-10043-z

Jamal, A., Jamal, A. M., & Yusof, S. M. (2023). Children as Earth Authors: A Story of Creativity, Metacognition and Motivation among Indian School Children. *Journal of Creative Behavior*, *57*(3), 450–465. Scopus. https://doi.org/10.1002/jocb.591

Jawaid, I., Javed, M. Y., Jaffery, M. H., Akram, A., Safder, U., & Hassan, S. (2020). Robotic system education for young children by collaborative-project-based learning. *Computer Applications in Engineering Education*, *28*(1), 178–192. Scopus. https://doi.org/10.1002/cae.22184

Kaldi, S., & Zafeiri, S. (2023). Identifying reflective modes in pre-service teachers' written reflections on the implementation of project-based learning during the school practicum. *Frontiers in Education*, *7*. Scopus. https://doi.org/10.3389/feduc.2022.1072090

Kim, H. W., & Kim, M. K. (2021). A Case Study of Children's Interaction Types and Learning Motivation in Small Group Project-Based Learning Activities in a Mathematics Classroom. *Eurasia Journal of Mathematics, Science and Technology Education*, *17*(12). Scopus. https://doi.org/10.29333/ejmste/11415

Larkin, K., & Lowrie, T. (2023). Teaching Approaches for STEM Integration in Pre- and Primary School: A Systematic Qualitative Literature Review. *International Journal of Science and Mathematics Education*, *21*, 11–39. Scopus. https://doi.org/10.1007/s10763-023-10362-1

LeTendre, G. K., & Gray, R. (2024). Social robots in a project-based learning environment: Adolescent understanding of robot–human interactions. *Journal of Computer Assisted Learning*, *40*(1), 192–204. Scopus. https://doi.org/10.1111/jcal.12872

Lombardi, L., Mednick, F. J., De Backer, F., & Lombaerts, K. (2022). Teachers' Perceptions of Critical Thinking in Primary Education. *International Journal of Instruction*, *15*(4), 1–16. Scopus. https://doi.org/10.29333/iji.2022.1541a

Lu, S.-Y., Lo, C.-C., & Syu, J.-Y. (2022). Project-based learning oriented STEAM: the case of micro–bit paper-cutting lamp. *International Journal of Technology and Design Education*, *32*(5), 2553–2575. Scopus. https://doi.org/10.1007/s10798-021-09714-1

McNerney, K., & Hall, N. (2020). Developing a framework of scientific enquiry in early childhood: An action research project to support staff development and improve science teaching. In *Early Years Science Education* (pp. 28–42). Routledge.

Muller, I., & Wood, L. (2021). Raising awareness of agency to address climate change: The do one thing (dot) strategy1. *Educational Research for Social Change*, *10*(2), 47–62. Scopus. https://doi.org/10.17159/2221-4070/2021/v10i2a4

Ndiung, S., & Menggo, S. (2024). Project-Based Learning in Fostering Creative Thinking and Mathematical Problem-Solving Skills: Evidence from Primary Education in Indonesia. *International Journal of Learning, Teaching and Educational Research*, *23*(8), 289–308. Scopus. https://doi.org/10.26803/ijlter.23.8.15

Parwoto, P., Ilyas, S. N., Bachtiar, M. Y., & Marzuki, K. (2024). Fostering creativity in kindergarten: The impact of collaborative project-based learning. *South African Journal of Childhood Education*, *14*(1). Scopus. https://doi.org/10.4102/sajce.v14i1.1462

Pratami, D., Akhmal, N. H., Maulana, M. I. I. M., & Hassan, S. A. H. S. (2024). INTRODUCING PROJECT-BASED LEARNING STEPS TO THE PRESCHOOL TEACHERS IN BANDUNG, INDONESIA. *Journal of Technology and Science Education*, *14*(3), 883–902. Scopus. https://doi.org/10.3926/jotse.2398

Purnomo, H., Karim, A., Mansir, F., & Valero-Matas, J. A. (2022). Covid-19 Pandemic: Project-Based Learning as Interprofessional Learning Model to Improve Student With Special Needs' Self Efficacy. *Sociologia y Tecnociencia*, *12*(2), 284–306. Scopus. https://doi.org/10.24197/st.2.2022.284-306

Rahmat, M. Y., & Rufaida, S. (2023). VALIDITAS MODUL DIGITAL BERBASIS PROJECT-BASED LEARNING UNTUK MENINGKATKAN KREATIVITAS SAINS. *PEDAGOGIA*, *19*(3), 191–205.

Rocha, S. S. (2024). Multiliteracies and Theatrical Education: Experience with English as an Additional Language Teaching at a Public School in Brazil. *International Journal of Literacies*, *31*(2), 77–100. Scopus. https://doi.org/10.18848/2327-0136/CGP/v31i02/77-100

Sanz, C. V., Artola, V., & Baldassarri, S. (2024). Developing educational serious games as a proposal for university training in the area of Child Computer Interaction. *International Journal of Child-Computer Interaction*, *41*. Scopus. https://doi.org/10.1016/j.ijcci.2024.100672

Soedjono, S., Yusuf, M., & Yuwono, J. (2022). Project-Based Learning and Health-Promoting Lifestyle for Students with Disability in COVID-19. *Health Education and Health Promotion*, *10*(1), 63–67. Scopus. Retrieved from Scopus.

Stojanović, B. J., Ristanović, D., Živković, P., & Džaferović, M. (2023). Project-Based Learning in Early Childhood Education in Serbia: First Experiences of Preschool Teachers. *International Journal of Cognitive Research in Science, Engineering and Education*, *11*(2), 213–220. Scopus. https://doi.org/10.23947/2334-8496-2023-11-2-213-220

Sun, L., Guo, Z., & Zhou, D. (2022). Developing K-12 students' programming ability: A systematic literature review. *Education and Information Technologies*, *27*(5), 7059–7097. Scopus. https://doi.org/10.1007/s10639-022-10891-2

Tang, K.-S., McLure, F., Williams, J., & Donnelly, C. (2024). Investigating the role of self-selected STEM projects in fostering student autonomy and self-directed learning. *Australian Educational Researcher*, *51*(5), 2355–2379. Scopus. https://doi.org/10.1007/s13384-024-00696-2

Vartiainen, J., & Kumpulainen, K. (2020). Playing with science: Manifestation of scientific play in early science inquiry. *European Early Childhood Education Research Journal*, *28*(4), 490–503.

Veraksa, A. N., Plotnikova, V. A., & Ivenskaya, P. R. (2024). Development of Social Competence in Preschoolers with Different Levels of Executive Functions: Role Play and Project-based Learning. *Psychological Science and Education*, *29*(3), 96–112. Scopus. https://doi.org/10.17759/pse.2024290306

Wedi, A., Sulthoni, S., Soepriyanto, Y., Prihatmoko, Y., Abdurrokhim, A., & Setyorini, E. (2020). *Penguatan model pembelajaran inovatif guru untuk pendidikan karakter di sekolah dasar*.

Wise, C. N., & Ward, A. E. (2023). Designing Culturally Responsive Literacy Centers to Include and Go Beyond Skills. *Reading Teacher*, *76*(5), 646–652. Scopus. https://doi.org/10.1002/trtr.2152

Zimmerman, H. T., Grills, K. E., McKinley, Z., & Kim, S. H. (2022). Families' engagement in making activities related to aerospace engineering: Designing for parents as learning partners in pop-up makerspaces. *Information and Learning Science*, *123*(3–4), 154–178. Scopus. https://doi.org/10.1108/ILS-08-2020-0190