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Development of Project-Based Learning Instructional Materials Integrated with Realia to Enhance Science Literacy in Early Childhood Education

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Abstract: Science literacy is a fundamental competence that should be fostered from early childhood through meaningful and contextual learning experiences. However, science instruction in many early childhood education settings remains teacher-centered and provides limited opportunities for children to explore scientific concepts using concrete learning media. This study aimed to develop and evaluate Project-Based Learning (PjBL) instructional materials integrated with realia media to improve science literacy among children aged 5–6 years at TK Al Khidmah, Tegal City. A Research and Development (R&D) approach using the ADDIE model was employed, including the stages of analysis, design, development, implementation, and evaluation. The study involved 20 children, two classroom teachers, and two expert validators. Data were collected through observations, interviews, questionnaires, documentation, and science literacy assessments, and analyzed using descriptive statistics, N-Gain, and paired-sample *t*-tests. The results showed that the instructional materials achieved high validity and practicality and were associated with significant improvements in children's science literacy, particularly in observing, questioning, classifying, drawing conclusions, and communicating scientific findings. Although the participants did not include children formally identified with special educational needs, the instructional materials incorporated flexible project activities, collaborative learning, and teacher scaffolding to accommodate diverse learning characteristics. These findings suggest that the developed instructional materials provide a feasible and promising approach for supporting contextual, inquiry-based, and more inclusive science learning in early childhood education.

Keywords: project-based learning; realia media; science literacy; inclusive early childhood education; instructional materials development.

INTRODUCTION

Science learning in early childhood plays a fundamental role in developing children's curiosity, scientific thinking, and scientific literacy. For children aged 5–6 years, scientific literacy extends beyond acquiring basic scientific concepts to include observing, questioning, exploring the surrounding environment, and connecting scientific phenomena with everyday experiences (Suryani & Setiawan, 2021; Sakina et al., 2025). These competencies provide an important foundation for later learning while fostering critical thinking and problem-solving skills (OECD, 2020; Sriwahyuni & Eliza, 2024). Therefore, science learning should provide meaningful and authentic experiences that actively engage children in knowledge construction.

Project-Based Learning (PjBL) is widely recognized as an effective instructional approach for developing scientific literacy because it places children at the center of the learning process through authentic projects and direct exploration (Bell, 2020). In early childhood education, PjBL encourages children to investigate real-life problems, collaborate with peers, communicate ideas, and construct knowledge through meaningful experiences appropriate to their developmental stages (Handayani et al., 2022; Ramadhani et al., 2025). This approach is also consistent with the Merdeka Curriculum, which emphasizes learner-centered instruction, authentic learning, and the development of twenty-first-century competencies. The implementation of PjBL in kindergarten generally involves identifying essential questions, collaborative planning, project implementation, presentation of project outcomes, and reflective evaluation (Khairiah et al., 2025). As emphasized by Sriwahyuni

and Eliza (2024), systematic project planning is essential for ensuring meaningful learning experiences.

Recent developments further highlight that effective PjBL should be implemented within inclusive learning environments that recognize children's diverse developmental characteristics. Children differ in their cognitive, physical, social, communicative, and learning profiles; therefore, instructional activities should provide flexible opportunities for participation and appropriate teacher scaffolding. Inclusive project-based learning enables children to explore, collaborate, and solve problems in line with their developmental readiness while promoting equitable participation. Consequently, instructional materials should be designed not only to improve scientific literacy but also to accommodate learner diversity within inclusive early childhood classrooms.

The effectiveness of PjBL is closely associated with the use of concrete learning media. Realia media utilize authentic objects from children's surrounding environments, enabling multisensory and contextual learning experiences that reduce the abstract nature of science concepts (Putri & Kurniawan, 2023; Nurhasanah & Wahyuni, 2021). From an inclusive education perspective, realia also provide accessible learning opportunities because children can observe, manipulate, discuss, and experiment with real objects according to their developmental readiness. Such flexibility supports active participation while minimizing learning barriers. Sakina et al. (2025) further reported that project-based science learning incorporating real objects and loose parts significantly enhances children's scientific literacy.

Scientific literacy in early childhood refers to children's ability to understand simple natural phenomena, conduct observations, ask questions, classify objects, predict outcomes, draw simple conclusions, and communicate their findings (OECD, 2020; Suryani & Setiawan, 2021). These competencies encompass scientific knowledge, science process skills, and scientific attitudes that develop simultaneously through active, contextual, and experiential learning (Khairiah et al., 2025). Accordingly, learning environments should encourage exploration rather than memorization, enabling children to construct scientific understanding through authentic experiences.

Previous studies consistently demonstrate that integrating PjBL with realia media positively influences children's scientific literacy. Rahmawati et al. (2024) reported significant improvements in children's abilities to observe, question, and explain simple scientific phenomena through project-based learning using real objects. Similar findings were reported by Yunita and Hidayat (2022) and Khairiah et al. (2025), indicating that PjBL enhances children's engagement, conceptual understanding, and science process skills. Nevertheless, many early childhood teachers continue to experience difficulties in designing systematic instructional materials, selecting appropriate realia, and developing scientific literacy assessments that align with children's developmental characteristics (Sari & Widodo, 2020; Pratiwi et al., 2025).

Preliminary observations conducted at TK Al Khidmah, in Tegal City, revealed similar challenges. Science learning remained predominantly teacher-centered and relied heavily on lectures and worksheets, limiting children's opportunities to explore scientific phenomena through authentic experiences. The use of real objects as learning media remained minimal, resulting in low levels of children's scientific literacy, particularly in observing, questioning, and communicating scientific findings. These findings indicate that improving science learning requires not only an effective instructional model but also comprehensive instructional materials that support teachers in implementing project-based learning systematically.

Although previous studies have demonstrated the effectiveness of PjBL and realia media, several research gaps remain. Existing studies primarily focus on learning outcomes rather than developing comprehensive instructional materials that integrate project planning, realia utilization, implementation procedures, and authentic scientific literacy assessment. Furthermore, limited attention has been paid to designing instructional materials that accommodate learner diversity through flexible and accessible learning experiences in inclusive early childhood classrooms. Addressing these gaps, this study develops Project-Based Learning instructional materials integrated with realia media to enhance scientific literacy among children aged 5–6 years at TK Al Khidmah, Tegal City. The study contributes theoretically by integrating project-based science learning with inclusive pedagogical principles and contributes practically by providing systematic instructional materials that support meaningful, contextual, and accessible science learning in early childhood education.

METHOD

This study employed a Research and Development (R&D) approach to produce Project-Based Learning (PjBL) instructional materials integrated with realia media and examine their validity, practicality, and effectiveness in improving scientific literacy among early childhood learners. The R&D approach was selected because it enables a systematic product development process grounded in field needs and incorporates continuous evaluation throughout the development stages (Sugiyono, 2019; Richey & Klein, 2020; Rahayu, 2025). The application of R&D in early childhood education is particularly relevant because it not only examines theoretical concepts but also addresses practical instructional problems by developing contextually relevant and applicable learning products (Rahayu, 2025).

The development process adopted the ADDIE model, consisting of Analysis, Design, Development, Implementation, and Evaluation. This model was selected because of its systematic yet flexible framework for developing instructional materials and its emphasis on continuous evaluation throughout the development process (Molenda, 2021; Rustandi & Darmawati, 2025). In addition, ADDIE has been widely used to develop Project-Based Learning instructional designs that promote active, learner-centered, and contextual learning experiences (Shiddiq et al., 2024).

The study was conducted at TK Al Khidmah, South Tegal District, Tegal City, Indonesia, over a two-month period from September to October 2025. The participants consisted of 20 children aged 5–6 years in Group B (14 boys and 6 girls), two classroom teachers who implemented the instructional materials and completed the practicality questionnaires, and two expert validators comprising one subject-matter expert and one instructional media expert. No participating child had been formally identified as having special educational needs. Nevertheless, the developed instructional materials were designed using flexible project activities, teacher scaffolding, collaborative learning, and multisensory realia experiences to accommodate children's diverse developmental characteristics and support implementation in inclusive early childhood classrooms. The research activities included needs analysis, instructional design, product development, expert validation, limited field implementation, and evaluation of product quality.

The development procedure followed the five stages of the ADDIE model. First, the Analysis stage aimed to identify instructional needs, learner characteristics, and problems encountered in science learning. Data were collected through classroom observations, teacher interviews, and documentation analysis of existing instructional materials. The analysis focused on children's scientific literacy levels and the limitations of science

instruction, which relied predominantly on teacher explanations and worksheets with limited use of concrete learning media. This stage ensured that the developed instructional materials reflected authentic classroom needs (Branch & Kopcha, 2021). These findings are consistent with Karnoto et al. (2025), who emphasize that project-based science learning requires instructional materials aligned with children's developmental characteristics and contextual learning environments.

Second, the Design stage involved preparing a blueprint for Project-Based Learning instructional materials integrated with realia media. Activities included formulating learning outcomes, developing teaching modules and daily lesson plans (RPPH), designing contextual science projects, selecting appropriate realia media, and planning authentic assessment procedures. The instructional design emphasized concrete exploration, collaboration, play-based learning, and meaningful scientific inquiry, allowing children to construct knowledge through direct interaction with real objects (Pratiwi et al., 2025). This approach supports the findings of Shiddiq et al. (2024), who report that PjBL effectively develops twenty-first-century competencies through contextual and collaborative learning.

Third, the Development stage focused on producing the instructional materials, including teaching modules, project scenarios, realia media, student activity guides, and scientific literacy assessment instruments. The assessment instrument was developed based on early childhood scientific literacy indicators identified in the literature, including observing, questioning, classifying, predicting, experimenting, drawing simple conclusions, and communicating scientific findings. Prior to implementation, the instruments and instructional materials were validated by one subject-matter expert and one instructional media expert to evaluate content relevance, language clarity, instructional design, media suitability, and alignment with children's developmental characteristics. Suggestions from both experts were incorporated during a revision process to improve product quality before field implementation. The expert validation process ensured adequate content validity and instructional feasibility (Akker et al., 2021).

Fourth, the Implementation stage involved a limited field trial with children in Group B. Classroom teachers facilitated the learning process using the developed instructional materials while researchers observed children's participation, scientific literacy development, and the fidelity of Project-Based Learning implementation. Although no child with formally identified special educational needs participated in this study, the instructional activities were implemented through flexible grouping, differentiated teacher support, and varied learning interactions to maximize participation among children with diverse learning characteristics and developmental readiness. This implementation stage generated empirical evidence regarding the practicality and effectiveness of the developed instructional materials (Thiagarajan et al., 2020; Sakina et al., 2025; Karnoto et al., 2025).

Finally, the Evaluation stage consisted of formative evaluation conducted throughout every ADDIE phase and summative evaluation performed after implementation. Product effectiveness was assessed by comparing children's scientific literacy before and after the intervention, whereas practicality was evaluated through teacher response questionnaires and classroom observations. Findings from this stage informed the final revision of the instructional materials.

Data were collected through observations, interviews, questionnaires, and documentation. Observation sheets were designed to assess children's scientific literacy across seven indicators: observing, questioning, classifying, predicting, experimenting, drawing simple conclusions, and communicating scientific findings. Interview guides were used to explore teachers' perceptions of the implementation of Project-Based Learning and

the use of realia. Questionnaires were administered to obtain expert validation and teacher practicality data, while documentation was employed to support classroom observations and record the implementation process.

The collected data were analyzed using both qualitative and quantitative descriptive techniques. Qualitative data obtained from classroom observations and interviews were analyzed through data reduction, data display, and conclusion drawing. Quantitative data from expert validation and teacher response questionnaires were analyzed using percentage scores to determine product validity and practicality. The effectiveness of the instructional materials was examined using paired-sample t-tests because the study compared children's scientific literacy before and after implementation within the same group participant. Prior to hypothesis testing, normality and homogeneity assumptions were examined to ensure the appropriateness of parametric statistical analysis. Furthermore, N-Gain analysis was conducted to determine the magnitude of improvement in children's scientific literacy, providing complementary evidence regarding the educational effectiveness of the developed instructional materials rather than merely identifying statistical significance (Hake, 1998; Field, 2022).

FINDING AND DISCUSSION

Finding(s)

This study aimed to develop and evaluate the quality of Project-Based Learning (PjBL) instructional materials integrated with realia media to enhance scientific literacy among children aged 5–6 years at TK Al Khidmah, Tegal City. The product was developed using the ADDIE model and evaluated for validity, practicality, and effectiveness.

Results of the Needs Analysis Stage

Preliminary observations, teacher interviews, and document analysis revealed that science learning at TK Al Khidmah still predominantly relied on lectures, question-and-answer sessions, and worksheets, with limited use of concrete learning media. Consequently, children had few opportunities to actively explore their environment, resulting in relatively low scientific literacy, particularly in observing, asking questions, communicating findings, and drawing simple conclusions. The analysis also indicated that teachers experienced difficulties in designing systematic Project-Based Learning activities and selecting appropriate realia media that corresponded to children's developmental characteristics. These findings confirmed the need for instructional materials that integrate contextual science projects with authentic learning experiences to improve children's scientific literacy.

Results of the Instructional Design Stage

Based on the needs analysis, a Project-Based Learning instructional guide, integrated with realia media, was developed around the theme *"Plants."* The instructional materials included learning objectives, teaching modules, daily lesson plans (RPPH), project activity scenarios, realia-based learning resources, and scientific literacy assessment instruments.

The central project involved planting and caring for bok choy vegetables through a sequence of activities, including observation, planting, maintenance, recording plant growth, discussion, and presentation of project outcomes. The scientific literacy indicators assessed in this study included children's ability to observe, classify, predict, draw simple conclusions, and communicate their observation results. The instructional design emphasized active participation, collaborative learning, and direct interaction with authentic objects. Several design displays of the instructional tools are presented in Figure 1.

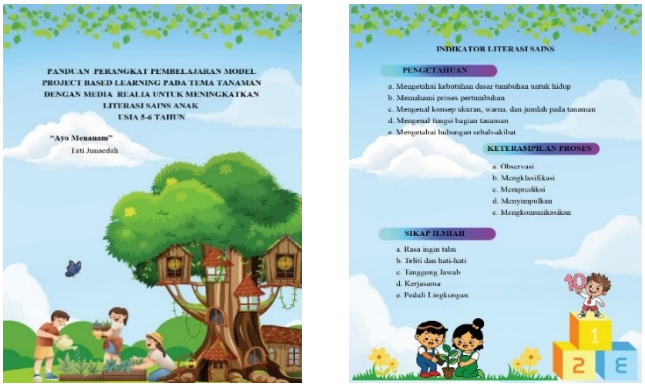


Figure 1. Cover and Indicators of the Instructional Design

Results of the Development and Product Validation Stage

The developed instructional materials were validated by two experts comprising one subject matter expert and one early childhood learning media expert. Validation covered four aspects: content feasibility, language, presentation, and suitability for children's developmental characteristics.

Table 1. Expert Validation Results of the Instructional Tools

Assessed Aspect	Mean Score	Percentage (%)	Category
Content Feasibility	4.45	89.00	Very Valid
Language	4.30	86.00	Very Valid
Presentation	4.40	88.00	Very Valid
Suitability for Children's Characteristics	4.55	91.00	Very Valid
Overall Mean	**4.43**	**88.60**	**Very Valid**

Overall, the instructional materials achieved an average validity score of 88.60%, indicating they were highly valid and suitable for classroom implementation with only minor revisions. The validators concluded that the project activities were developmentally appropriate, the instructional procedures were clearly organized, and the integration of realia media effectively supported meaningful science learning. Suggestions from the experts mainly focused on improving several instructional illustrations and refining activity instructions to facilitate classroom implementation.

Results of the Implementation Stage

Following expert revision, the instructional materials were implemented through a limited field trial involving Group B children at TK Al Khidmah. During implementation, children actively participated in each stage of the planting project, including preparing the planting medium, planting seeds, watering plants, observing growth, discussing findings, and presenting the project results.

Classroom observations indicated that children became increasingly engaged throughout the learning process. Compared with the initial observations, they demonstrated greater curiosity, participated more actively in exploration activities, and showed increasing confidence when interacting with real objects during science learning.

Results of Product Practicality

The practicality of the instructional materials was evaluated through teacher response questionnaires administered after the implementation stage. The assessment covered ease of use, clarity of instructional procedures, suitability of the learning time allocation, and the use of realia.

Table 2. Teacher Responses on Instructional Tool Practicality

Practicality Aspect	Percentage (%)	Category
Ease of Use	92.00	Very Practical
Clarity of Learning Steps	90.00	Very Practical
Suitability with Learning Time	88.00	Practical
Attractiveness of Realia Media	94.00	Very Practical
Overall Mean	**91.00**	**Very Practical**

The instructional materials received an overall practicality score of 91.00%, indicating they were highly practical for classroom implementation. Teachers reported that the instructional guide was easy to understand, project activities were well organized, and the required realia media were readily available in the surrounding environment. They also considered the project activities effective in encouraging children's active participation while remaining feasible within the allocated instructional time.

Results of Product Effectiveness

The effectiveness of the developed instructional materials was examined by comparing children's scientific literacy scores before and after the implementation of Project-Based Learning supported by realia media. The results showed a substantial improvement in children's scientific literacy. The average pretest score increased from 49.00 to 77.50 on the posttest, a gain of 28.50 points. The calculated N-Gain value was 0.91, indicating a high level of improvement.

Table 3. Comparison of Children's Scientific Literacy Pretest and Posttest Scores

Test Phase	Mean Score	Category
Pretest	49.00	Low
Posttest	77.50	High
Score Gain	28.50	–

These findings demonstrate that the developed instructional materials effectively enhanced children's abilities to observe, classify, predict, draw simple conclusions, and communicate scientific findings through authentic project activities.

Normality Test and Paired Sample t-Test

Prior to hypothesis testing, the normality of the data was examined using the Kolmogorov–Smirnov test. The analysis yielded a significance value of 0.069 ($p > 0.05$), indicating that the data were normally distributed. The paired-sample *t*-test yielded a p-value of 0,049 ($p < 0,05$), indicating a statistically significant difference in children's scientific literacy before and after the implementation of the instructional materials. These statistical findings support the effectiveness of Project-Based Learning integrated with realia media in improving scientific literacy among children aged 5–6 years.

Variations in Children's Learning Outcomes and Classroom Observations

Although all participating children demonstrated improvement, the degree of progress varied. Of the 20 children, 15 children (75%) achieved a high level of improvement, while 5 children (25%) demonstrated a moderate level of improvement. No child showed low improvement, indicating that the instructional materials benefited all participants despite differences in learning progress.

Classroom observations further revealed meaningful changes in children's scientific learning behaviors throughout the project. Children gradually became more willing to ask questions, carefully observe changes in plant leaves and growth, compare plant height, discuss observations with peers, and explain their findings during classroom discussions. These behaviors reflected increasing curiosity, collaboration, and confidence in conducting simple scientific investigations.

Several challenges were also identified during implementation. Some children were initially reluctant to present their project results to the class, while others found it difficult to wait patiently for plants growth or needed teacher guidance when making observations and drawing simple conclusions. These findings suggest that teacher scaffolding remained essential for supporting children with different levels of developmental readiness and participation.

Teacher responses supported the observational findings. Teachers reported that children became considerably more active during science learning, and several children who had previously been passive began asking questions, participating in discussions, and showing greater interest in scientific exploration. Overall, the project-based activities created a more engaging and interactive learning environment while accommodating differences in children's learning pace through continuous teacher support.

Summary of Research Findings

Overall, the findings demonstrate that the Project-Based Learning instructional materials integrated with realia media successfully met the three quality criteria of educational product development. First, the instructional materials were categorized as **very valid**, based on expert evaluations of content, language, presentation, and developmental appropriateness. Second, they were considered very practical, as teachers found them easy to implement using locally available realia media and well suited to classroom conditions. Third, the instructional materials proved highly effective in improving children's scientific literacy, as evidenced by significant gains in pretest-posttest scores, a high N Gain value, and statistically significant *t*-test results.

In addition to quantitative improvements, classroom observations showed positive changes in children's curiosity, scientific inquiry skills, communication, and collaborative learning behaviors. Although some children required additional guidance during observation, presentation, and conclusion-making activities, all participants demonstrated meaningful progress in learning. These findings indicate that the developed instructional materials are not only effective in improving scientific literacy but also sufficiently flexible to accommodate individual differences through appropriate teacher facilitation and scaffolding.

Discussion(s)

This study examined the development of Project-Based Learning (PjBL) instructional materials integrated with realia media to improve scientific literacy among children aged 5–6 years at TK Al Khidmah, Tegal City. The discussion focuses on the identified learning needs, the validity and practicality of the developed instructional materials, and their implications for strengthening science learning in early childhood education.

The needs analysis revealed that science learning at TK Al Khidmah remained predominantly teacher-centered, relying on lectures, worksheets, and question-and-answer activities with limited opportunities for children to explore real objects. As a result, children's scientific literacy, particularly their abilities to observe, ask questions, communicate findings, and construct simple scientific explanations, had not developed to its full potential. This finding is consistent with Early et al. (2020), who emphasize that early childhood science learning should be grounded in direct experiences to stimulate curiosity and science process skills. Similar findings were reported by Sari and Mulyadi (2021), who found that science instruction lacking contextual learning resources limits children's opportunities to explore and communicate scientific ideas.

More importantly, the present findings suggest that low scientific literacy should not be viewed solely as a limitation of children's abilities. Instead, it reflects the limited availability of learning environments that encourage inquiry, exploration, and authentic scientific experiences. This perspective extends previous studies by highlighting instructional design as a determining factor in developing scientific literacy. Consequently, improving children's scientific literacy requires not only curriculum enhancement but also the provision of instructional materials that systematically connect scientific concepts with meaningful learning experiences.

The expert validation results indicated that the developed instructional materials were rated as highly valid in terms of content feasibility, language, presentation, and suitability for children's developmental characteristics. These findings support the framework proposed by Plomp and Nieveen (2020), who argue that high-quality instructional products require coherence among learning objectives, instructional activities, media, and assessment. Likewise, Kokotsaki et al. (2021) emphasize that the effectiveness of Project-Based Learning is strongly influenced by systematic instructional planning, while Fitria et al. (2023) conclude that well-validated instructional materials contribute substantially to successful classroom implementation in early childhood education.

Beyond confirming previous studies, the present research demonstrates that integrating Project-Based Learning syntax, realia media, and scientific literacy assessment into a single instructional package creates stronger pedagogical coherence than developing these components separately. Unlike many previous studies that focused primarily on evaluating learning models or instructional media, this study developed a comprehensive instructional package consisting of teacher guidance, project scenarios, authentic learning resources, and assessment instruments specifically designed for early childhood science learning. This integrated approach represents an important contribution to instructional design by providing teachers with a practical framework that directly links learning objectives, classroom implementation, and assessment.

The teacher response questionnaires further indicated that the developed instructional materials were highly practical, reflecting their ease of use, clarity of instructional procedures, suitability for classroom implementation, and accessibility of realia. These findings are consistent with Han et al. (2021), who argue that practicality is a key determinant of the sustainability of Project-Based Learning implementation. Similarly, Wulandari and Setiawan (2022) reported that project-based instructional materials supported

by concrete media are more readily adopted by early childhood teachers than abstract or text-based instructional resources.

The high level of practicality observed in this study can also be explained by the contextual use of realia obtained from children's immediate environment. Because teachers utilized readily available materials rather than expensive commercial resources, the instructional materials required minimal preparation while maintaining meaningful learning experiences. This practical characteristic increases the likelihood that the developed instructional materials can be implemented consistently across different early childhood classrooms. Therefore, this study's contribution extends beyond producing valid instructional materials by demonstrating that effective science learning innovation should also be feasible, sustainable, and closely connected to children's everyday experiences.

The findings demonstrate a significant improvement in children's scientific literacy, as indicated by the high N Gain score and the statistically significant difference between pretest and posttest results. However, the contribution of this study extends beyond confirming the effectiveness of Project-Based Learning (PjBL). The improvement appears to be closely related to the interaction among project activities, authentic learning contexts, and the use of realia, which enabled children to actively construct scientific understanding through observation, experimentation, and discussion. Rather than merely receiving information, children developed scientific concepts through direct experiences, making learning more meaningful and cognitively engaging. This interpretation supports Bustamante et al. (2022), who reported that PjBL strengthens observation, prediction, and communication skills, and Hsin et al. (2020), who emphasized that authentic project experiences stimulate deeper scientific reasoning among preschool children. Similar findings were reported nationally by Lestari et al. (2024), who found that project-based learning supported by realia media significantly improves children's abilities to observe and communicate scientific findings. These findings are also consistent with International studies, which emphasize that active participation and flexible instructional strategies enable children with diverse learning characteristics to engage meaningfully in classroom learning (Angreni et al., 2026).

An equally important finding is that children's responses to the instructional activities were not completely uniform. Although fifteen children demonstrated great improvement, five showed moderate gains because they required additional teacher guidance when making observations, drawing conclusions, or communicating their findings. Several children also had difficulty waiting patiently for gradual growth of plants and initially felt reluctant to present project results to their classmates. These variations indicate that scientific literacy develops through different learning trajectories and that project-based learning should be accompanied by appropriate instructional scaffolding. The gradual reduction of teacher assistance enabled children to become increasingly independent throughout the project, suggesting that the effectiveness of PjBL depends not only on project activities themselves but also on responsive teacher facilitation that accommodates individual learning differences. Differentiated instructional support and responsive scaffolding improve participation among learners with varying academic readiness and learning characteristics (Andini et al., 2025).

The use of realia media also emerged as an important factor in the development of children's scientific literacy. Real objects allowed children to connect abstract scientific concepts with observable phenomena, thereby encouraging repeated observation, comparison, and simple reasoning. During the planting project, children naturally compared plant height, observed changes in leaf color, discussed differences in growth, and explained their findings in their own words. Such multisensory experiences promoted not only

conceptual understanding but also scientific communication and collaborative inquiry. These findings support Siraj-Blatchford (2021), who argued that concrete materials facilitate children's construction of scientific knowledge, as well as Putra and Yuliani (2023), who demonstrated that realia media increase children's engagement and conceptual understanding during science learning. Learning environments offering multiple forms of interaction with instructional materials improve accessibility and participation for children with diverse learning profiles, including those requiring additional instructional support (Harini et al., 2026).

An important theoretical contribution of this study is to demonstrate that PjBL integrated with realia media should be understood not merely as an instructional strategy but as an adaptive learning ecosystem capable of accommodating learner diversity. Although no children participating in this study were formally identified as having special educational needs, the instructional guide intentionally incorporated flexible project activities, collaborative learning, multiple opportunities for observation, and teacher scaffolding to enable implementation in inclusive classrooms. These characteristics provide opportunities for children with different learning speeds, communication abilities, or participation patterns to remain actively engaged within the same learning environment. Consequently, the novelty of this study lies not only in developing validated instructional materials but also in proposing an adaptable design that bridges scientific literacy, project-based pedagogy, and inclusive early childhood education. Universal Design for Learning principles and flexible classroom practices should become integral components of instructional innovation to ensure equitable participation for all learners (Listyowati et al., 2025).

Overall, this study contributes both theoretically and practically to early childhood education. Theoretically, it extends prior PjBL research by explaining why project-based science learning, supported by realia media, effectively develops scientific literacy through authentic inquiry, collaborative interaction, and contextual experiences rather than simply confirming its effectiveness. Practically, the instructional guide provides teachers with a systematic, feasible, and adaptable model that can be implemented across various early childhood settings. Future studies should examine the implementation of this model in fully inclusive classrooms involving children with diverse disabilities and learning needs, investigate its long-term effects on scientific literacy development, and evaluate how adaptive instructional supports can further strengthen equitable participation and learning outcomes for all children.

CONCLUSION

This study successfully developed a Project-Based Learning (PjBL) instructional guide integrated with realia media to enhance scientific literacy among children aged 5–6 years at TK Al Khidmah, Tegal City. The findings indicate that the developed instructional tools meet the key quality criteria for educational product development. Expert validation confirmed that the guide was highly valid in terms of content, language, presentation, and suitability for early childhood developmental characteristics. Teacher evaluations further demonstrated that the instructional tools were highly practical, as they were easy to use, supported by clear instructional procedures, and effectively integrated realia media into science learning activities.

The evaluation of effectiveness revealed that the instructional guide significantly improved children's scientific literacy. Through project-based activities, children became more capable of observing, asking questions, classifying objects, drawing simple conclusions, and communicating their findings. The significant improvement in posttest scores, supported by a high N-Gain value and paired-samples statistical analysis, indicates

that integrating Project-Based Learning with realia media provides meaningful contextual learning experiences that effectively promote scientific literacy in early childhood.

The novelty of this study lies in the development of a systematic instructional guide that integrates Project-Based Learning, authentic experiences, and realia media into a structured model for early childhood science education. Although no participating children were formally identified as having special educational needs, the instructional guide incorporates flexible project activities, collaborative learning, and teacher scaffolding, allowing adaptation for children with diverse learning characteristics and supporting implementation in inclusive early childhood classrooms.

This study has several limitations. The implementation involved only one kindergarten with 20 children and was conducted over a relatively short period, limiting the generalizability of the findings and the evaluation of long-term impacts. Furthermore, the model has not yet been tested with children who have identified disabilities or special educational needs.

Future studies should examine the scalability of the instructional guide across diverse educational settings, including inclusive early childhood classrooms involving children with different learning needs. Longitudinal research is also recommended to investigate the sustainability of scientific literacy development and to explore the integration of differentiated instruction, assistive learning supports, and digital technologies to further strengthen inclusive and high-quality science learning in early childhood education.

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