

Empowering Prospective Elementary Teachers Through Project-Based Science Learning: Development of an Instructional Textbook

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Abstract: Science learning in elementary teacher education should extend beyond conceptual mastery by engaging prospective teachers in investigation and problem-solving. PjBL offers a relevant approach, yet textbooks integrating project-based learning models with elementary science education remain limited. This study aimed to develop a project-based learning textbook and examine its characteristics, validity, practicality, and effectiveness in improving science conceptual understanding among elementary teacher education students. The study employed Research and Development using the 4D model: define, design, develop, and disseminate. Product validity was assessed by three experts using the CVI, while practicality was evaluated by three teachers through a response questionnaire. Effectiveness was examined using a quasi-experimental non-equivalent control group design and analyzed using an independent-samples t-test. The results showed that the textbook was project-based, contextual, interactive, student-centered, and oriented toward 21st-century skills. Expert validation yielded a CVI of 0.90, indicating valid criteria, while the practicality score reached 82.45%. The average conceptual understanding gain was 21.375 points in the experimental group and 16.250 points in the control group. The independent-samples t-test yielded $p = 0.024 < 0.05$, indicating a significant difference between the groups. Thus, the textbook is valid, practical, and effective for supporting elementary science education.

Keywords: empowering, PBL, instructional textbook

Abstrak

Abstrak: Pembelajaran IPA dalam pendidikan guru sekolah dasar perlu melampaui penguasaan konsep dengan melibatkan calon guru dalam kegiatan investigasi dan pemecahan masalah. Pembelajaran berbasis proyek merupakan pendekatan yang relevan untuk mencapai tujuan tersebut, namun buku ajar yang mengintegrasikan berbagai model pembelajaran berbasis proyek dengan pendidikan IPA sekolah dasar masih terbatas. Penelitian ini bertujuan mengembangkan buku ajar berbasis pembelajaran proyek serta mengkaji karakteristik, validitas, kepraktisan, dan efektivitasnya dalam meningkatkan pemahaman konsep IPA mahasiswa pendidikan guru sekolah dasar. Penelitian menggunakan metodologi pengembangan dengan model pengembangan 4D yang meliputi tahap define, design, develop, dan disseminate. Validitas produk dinilai oleh tiga ahli menggunakan CVI, sedangkan kepraktisan dievaluasi oleh tiga guru melalui angket respons. Efektivitas diuji menggunakan desain quasi-experimental non-equivalent control group dan dianalisis menggunakan independent-samples t-test. Hasil penelitian menunjukkan bahwa buku ajar memiliki karakteristik berbasis proyek, kontekstual, interaktif, berpusat pada mahasiswa, dan berorientasi pada keterampilan abad ke-21. Hasil validasi ahli memperoleh CVI sebesar 0,90, yang menunjukkan bahwa produk memenuhi kriteria valid, sedangkan skor kepraktisan mencapai 82,45%. Peningkatan rata-rata pemahaman konsep sebesar 21,375 poin pada kelompok eksperimen dan 16,250 poin pada kelompok kontrol. Hasil independent-samples t-test menunjukkan $p = 0,024 < 0,05$, yang mengindikasikan adanya perbedaan yang signifikan antara kedua kelompok. Dengan demikian, buku ajar yang dikembangkan valid, praktis, dan efektif dalam mendukung pembelajaran IPA SD.

Keywords: penguatan, PBL, teks instruksional

INTRODUCTION

Science education at the elementary school level requires students not only to acquire conceptual knowledge but also to engage in activities involving observation, questioning, investigation, information analysis, and communication of findings. Therefore, science learning requires learning resources that can connect scientific concepts with active and contextual learning experiences. Textbooks have an important role in this process because they can systematically organize learning materials while providing activities that support active and independent learning (Ardianti et al., 2019; Syahroni et al., 2016).

The need for applicable learning resources becomes increasingly important in elementary school teacher education. Prospective elementary teachers are expected not only to understand science concepts but also to develop the ability to design science learning that corresponds to elementary students' characteristics and learning needs. Therefore, learning resources for prospective teachers should not be limited to theoretical explanations but should also provide practical examples of instructional models that can be adapted to elementary science classrooms (Beyer & Davis, 2011; Hasanah et al., 2026).

One approach that is relevant to this need is Project-Based Learning (PjBL). PjBL provides students with opportunities to learn through the completion of projects related to authentic problems and to produce a tangible product as part of the learning process (Utomo et al., 2020). This approach enables the integration of conceptual knowledge, investigation, collaboration, communication, and problem-solving. For example demonstrated that project-based learning can increase student engagement by providing student-centered learning experiences (Almulla, 2020).

Project-based learning is also closely associated with the development of 21st-century skills. Project activities provide opportunities for learners to analyze problems, formulate solutions, work collaboratively, develop products, and communicate their findings. Thus, PjBL has considerable potential to promote critical thinking, creativity, communication, and collaboration (Khafah & Suprpto, 2023).

In science education, project-based learning can further strengthen the relationship between scientific concepts and empirical experiences. Investigation-based activities enable learners to understand concepts through direct experiences rather than merely receiving declarative knowledge. PjBL can also be integrated with STEM or STEAM approaches and educational technology to provide broader learning experiences and promote problem-solving skills (Muzana et al., 2021; Rahmawati et al., 2020).

Although studies on project-based learning have increased considerably, many studies on learning-resource development still focus on modules, worksheets, or instructional materials designed for specific topics. Previous studies have developed inquiry-based modules supported by augmented reality, STEAM-oriented science materials, and project-based worksheets for elementary science education. However, a learning resource that comprehensively integrates various

project-based learning models specifically for prospective elementary school teachers remains necessary (Ilma et al., 2023; D. P. Lestari et al., 2024; Naradika et al., 2024).

This need provides the basis for developing the Project-Based Learning Models Textbook. The textbook was designed to include fundamental concepts of project-based learning, various relevant instructional models, project design and implementation, assessment, evaluation, and reflection. The structure was intended to bridge students' theoretical understanding with their ability to design project-based science learning for elementary schools.

The novelty of this study lies in the development of a comprehensive textbook for prospective elementary school teachers, rather than merely developing instructional materials for elementary students. The textbook was designed to enable teacher candidates to understand various project-based learning models while simultaneously developing their ability to design and implement those models in elementary science education.

Accordingly, this study aimed to: (1) describe the characteristics of the developed project-based learning textbook; (2) analyze the validity of the textbook; (3) analyze its practicality; and (4) examine its effectiveness in improving science conceptual understanding among elementary school teacher education students.

METHODOLOGY

This study employed a Research and Development (R&D) approach to produce a project-based learning textbook that met the criteria of validity, practicality, and effectiveness. The development procedure adopted the 4D model proposed by Thiagarajan et al. (1974), consisting of four stages: define, design, develop, and disseminate.

The define stage involved identifying problems and learning needs. The design stage involved developing the structure and content of the textbook. The textbook consisted of five main sections: (1) fundamental concepts of project-based learning; (2) project-based learning models in elementary science education; (3) project design and implementation; (4) assessment of project-based learning; and (5) evaluation and reflection. The develop stage involved expert validation, practicality testing, and effectiveness testing. The disseminate stage involved distributing the final product to potential users.

The effectiveness test involved fourth-semester students enrolled in the Elementary School Teacher Education Program, Faculty of Teacher Training and Education, Universitas Pamulang, during the second semester of the 2025/2026 academic year. Three experts participated in the product validation process, while three teachers participated as practitioners in the practicality assessment.

Three instruments were used in this study. First, an expert validation sheet was used to assess the content validity of the textbook. Second, a user-response questionnaire was used to assess the practicality of the textbook. Third, a science conceptual understanding test was administered to examine the effectiveness of the developed product.

Product validity was analyzed using the Content Validity Index (CVI). The CVI was calculated based on the proportion of items receiving ratings of 3 or 4

from the experts. The product was considered valid when the CVI reached at least 0.60. Practicality was analyzed using the percentage of scores obtained from practitioner responses. The effectiveness of the textbook was examined using an independent-samples t-test. Before the hypothesis test, normality and homogeneity tests were conducted to determine whether the data met the statistical assumptions. The experimental group received instruction using the developed project-based learning textbook, whereas the control group received conventional instruction. The effectiveness test employed a non-equivalent control group design, represented as follows:

Sampel	Pretest	Treatment	Posttest
RC	O ₁	X	O ₂
RC	O ₃		O ₄

Figure 1. Quasi-experimental design using a non-equivalent control group design.

DISCUSSION

1. Characteristics of the Developed Textbook

The developed product was a project-based learning textbook specifically designed to support elementary science education. The textbook had several major characteristics: project-based learning orientation, contextual learning, interactivity, 21st-century skill development, and authentic assessment. The project-based characteristic was reflected in the inclusion of essential questions, investigation activities, project development, collaboration, product creation, and reflection. The textbook did not merely explain the theoretical foundations of PjBL but also provided project activities, case studies, simple experiments, and collaborative assignments.



Figure 2. Cover of the Project-Based Science Learning Model Textbook

The contextual characteristic was reflected in the connection between learning materials and everyday problems, such as environmental pollution, alternative energy, the water cycle, and the utilization of materials available in the surrounding environment. Such contextualization enables prospective teachers to understand how science concepts can be taught through phenomena that are familiar to elementary school students. The textbook also integrated 21st-century skills through activities designed to promote critical thinking, creativity, collaboration, and communication. In addition, project activities were accompanied by learning objectives, materials, procedures, observation sheets, reflection activities, and assessment components (Saleha et al., 2026; Zakariah et al., 2026).

These characteristics are consistent with the principles of project-based learning, which emphasize student-centered learning and authentic experiences. PjBL can increase student engagement by positioning learners as active participants in the learning process (Burhan et al., 2025). Similarly, studies in science education have demonstrated the potential of PjBL to support problem-solving and higher-order thinking skills (Harjono et al., 2025; Pramasdyahsari et al., 2023). Thus, the main contribution of the developed textbook lies not simply in presenting project-based learning concepts but in integrating conceptual knowledge, learning activities, projects, assessment, and reflection into a single learning resource.

2. Textbook Validity

The expert validation results indicated that the textbook obtained an average CVI of 0.90. The product was evaluated by three experts in terms of content, language, and presentation.

Table 1. Expert Validation Results

Expert	CVI
Expert 1	0.85
Expert 2	1.00
Expert 3	1.00
Average CVI	0.90
Category	Valid

The results indicate that the textbook had a high level of content validity. Most indicators obtained high ratings. Several indicators obtained a CVI of 1.00, while some language-related indicators obtained a CVI of 0.67. The findings indicate that the textbook was generally considered appropriate in terms of content, language, and presentation. Nevertheless, the relatively lower scores on some language indicators suggest that minor revisions may still be required, particularly regarding punctuation, word choice, and language consistency.

The validity of a learning resource is important because an educational product should not only be visually attractive but also conceptually accurate, instructionally appropriate, and readable. The systematic organization of the textbook from fundamental concepts to implementation, assessment, evaluation,

and reflection also contributed to its validity. These findings support previous research emphasizing that the development of project-based learning materials requires validation of content, presentation, language, and instructional design before the product is implemented in actual learning environments (E. R. Lestari et al., 2022).

3. Textbook Practicality

The practicality assessment involved three teachers as practitioners. The textbook obtained a total score of 203 out of a maximum score of 255, corresponding to a practicality percentage of 82.45%.

Table 2. Practicality Assessment Results

Component	Result
Obtained score	203
Maximum score	255
Percentage	82.45%
Category	Very good

The result indicates that the textbook was considered practical for use in learning. The assessment covered aspects such as the clarity of learning objectives, availability of materials, suitability of learning procedures, language readability, visual presentation, ease of implementation, and contribution to student activity and understanding. The practicality of the textbook can be attributed to its systematic organization and the availability of operational guidance for project activities. Users were not only provided with theoretical explanations but also with examples of project activities, required materials, procedures, observation activities, and assessment components (Sukma & Shiyamsyah, 2024).

This structure can help reduce the gap between understanding the theory of project-based learning and implementing it in actual learning situations. Such practicality is particularly important for prospective teacher education because students need opportunities to understand not only what project-based learning is but also how it can be designed and implemented.

4. Effectiveness in Improving Conceptual Understanding

The effectiveness test compared the improvement in conceptual understanding between the experimental and control groups. The experimental group received instruction using the developed textbook, whereas the control group received conventional instruction. The normality test resulted in Kolmogorov-Smirnov significance values of 0.194 for the experimental group and 0.200 for the control group. Both values were greater than 0.05, indicating that the data were normally distributed.

The homogeneity test resulted in a significance value of 0.052, which was also greater than 0.05. Therefore, the variances of the two groups were considered homogeneous. The independent-samples t-test showed that the average increase in conceptual understanding was 21.375 points in the experimental group and 16.250 points in the control group.

Table 3. Improvement in Science Conceptual Understanding

Group Statistics

Kelompok		N	Mean	Std. Deviation	Std. Error Mean
Kenaikan_ Pemahaman_Konsep	Kelas Eksperimen	25	21,3750	8,77786	1,75557
	Kelas Kontrol	25	16,2500	6,56746	1,31349

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Kenaikan_ Pemahaman_Konsep	Equal variances assumed	3,956	,052	2,337	48	,024	5,12500	2,19255	,71658	9,53342
	Equal variances not assumed			2,337	44,459	,024	5,12500	2,19255	,70749	9,54251

The significance value of $0.024 < 0.05$ indicates a statistically significant difference in conceptual understanding gains between the experimental and control groups. The results suggest that students who learned using the developed project-based learning textbook achieved greater conceptual gains than those who received conventional instruction.

One possible explanation is the active learning experience facilitated by the textbook. Students were not merely exposed to conceptual explanations but were engaged in investigation, discussion, experimentation, problem-solving, product development, and reflection. Such activities provide opportunities for students to connect abstract scientific concepts with concrete experiences.

From a constructivist perspective, these experiences may facilitate deeper conceptual understanding because students actively construct meaning through interaction with problems and learning experiences. Project-based learning provides an instructional environment in which students can investigate authentic problems, apply knowledge, and reflect on the outcomes of their activities.

The finding is consistent with (Yuniwati & Sitepu, 2025), who reported that project-based learning can enhance student engagement through active and student-centered learning. It is also consistent with studies suggesting that project-based approaches can contribute to problem-solving and higher-order thinking in science learning (Dwipranoto et al., 2025).

However, the effectiveness claim in this study should be limited to the variable that was empirically measured. Although the characteristics of the textbook have the potential to support critical thinking, creativity, communication, collaboration, and science process skills, these variables were not independently tested as primary outcome variables in this study.

The study has both theoretical and practical implications, as the developed textbook can support active, meaningful, and project-based science learning while serving as an additional resource for lecturers and prospective teachers in designing and implementing elementary science instruction. However, the study is limited by the small number of experts and teachers involved, the single institutional context, and its focus on science conceptual understanding. Future research should therefore involve larger and more diverse samples and examine additional outcomes, such as science process skills, science literacy, critical thinking, creativity, collaboration, and prospective teachers' ability to design project-based science instruction.

CONCLUSION

This study resulted in a Project-Based Learning Models Textbook for elementary science education, characterized by a project-based, contextual, interactive, student-centered approach oriented toward 21st-century skills. The textbook was designed to connect science conceptual understanding with investigative experiences, project activities, learning products, assessment, and reflection. Based on assessments by three experts, the textbook obtained a Content Validity Index (CVI) of 0.90, indicating that it met the validity criteria. The practicality test based on responses from three teachers yielded a percentage of 82.45%, indicating that the product was suitable for use in learning. Meanwhile, the effectiveness test showed that the average increase in conceptual understanding was 21.375 in the experimental group, which was higher than 16.250 in the control group. The independent-samples t-test yielded a significance value of $p = 0.024 < 0.05$, indicating a significant difference in the improvement of conceptual understanding between the two groups. Therefore, the developed textbook met the criteria for validity and practicality and demonstrated effectiveness in improving science conceptual understanding among elementary school teacher education students. The product can be used as a learning resource in elementary science education, particularly to support the implementation of project-based learning. Future studies are recommended to examine the product using larger samples and to investigate other learning outcomes more specifically, such as science process skills, critical thinking, creativity, collaboration, and science literacy.

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