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Development of A Problem-Based Learning Teaching Module In Differentiated Instruction to Improve Science Literacy of 4th Grade Students

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Abstract

Science learning in elementary schools often faces challenges related to low science literacy and limited accommodation of students' diverse learning needs. These issues highlight the need for instructional designs that promote active learning while addressing individual differences. This study aims to develop and examine the effectiveness of a differentiated learning module based on the Problem-Based Learning (PBL) approach for teaching plant structure and function in elementary science education. The research employed a research and development method using the ADDIE model, consisting of analysis, design, development, implementation, and evaluation stages. The subjects included fourth-grade students and teachers from several elementary schools, with data collected through tests, questionnaires, observations, and interviews. Data analysis involved descriptive statistics, normality and homogeneity tests, paired samples t-tests, and N-gain analysis. The findings indicate that the developed module is valid, practical, and effective in supporting science learning. The implementation of differentiated PBL contributes to improved student engagement, conceptual understanding, problem-solving ability, and creative thinking in science learning contexts. The novelty of this study lies in the integration of differentiated instruction and PBL within a systematically designed elementary science module using the ADDIE framework. The study provides practical implications for teachers in designing inclusive science instruction and offers academic contributions to the development of innovative pedagogical models in elementary education.

Keywords ADDIE Model, Differentiated Learning, Elementary Science, Problem-Based Learning, Science Literacy

INTRODUCTION

In the last decade, global education systems have increasingly recognized the importance of science literacy as a core competency for students to thrive in the 21st century. International assessments such as the Programme for International Student Assessment (PISA) and Trends in

International Mathematics and Science Study (TIMSS) indicate that science literacy is strongly correlated with problem-solving, critical thinking, and global competitiveness (Glaze, 2018; Ulger, 2018). Despite worldwide reforms, science literacy levels remain uneven, with significant disparities between developed and developing countries. For example, the 2022 PISA report revealed that students in OECD countries averaged 483 in science literacy, whereas many developing nations scored well below this threshold (OECD, 2022). These findings emphasize the urgent global demand for effective teaching models that move beyond rote memorization towards inquiry-based and problem-centered learning (Tan et al., 2025).

In Asia, governments have responded by introducing innovative curricula and differentiated teaching strategies to address diverse student needs. Countries like Singapore, South Korea, and Japan have invested in problem-based learning (PBL) frameworks and teacher training to cultivate higher-order thinking skills and strengthen literacy across STEM subjects (Savvas, 2021). However, research highlights that many Asian classrooms still struggle with overly teacher-centered instruction, limiting students' opportunities to develop independence, collaboration, and creativity (Hadi et al., 2022). This suggests that while policy reforms exist, practical classroom implementation remains a persistent challenge.

Indonesia shares similar struggles. Although the merdeka belajar curriculum was introduced to replace Kurikulum 2013 and allow more flexible and student-centered approaches, learning outcomes remain unsatisfactory. Indonesian students scored only 383 in science literacy in the 2022 PISA test, far below the OECD average and behind neighboring Malaysia and Thailand (OECD, 2022). The International Education Achievement (IEA) survey also found that Indonesian elementary students ranked 29th out of 31 participating countries in reading literacy, showing a close link between low reading comprehension and weak science literacy (Schleicher, 2019; Ratnasari, 2020). Local evidence further confirms these findings, with declining literacy levels reported in several elementary schools across Sidoarjo District, including Cluster 02 Tulangan, where more than half of Grade 4 students scored below the minimum mastery criteria in science (based on supervision reports, 2024).

At the classroom level, teacher observations in Cluster 02 Tulangan show that differentiated instruction has not been optimally implemented. Teachers often assume uniform readiness across students, overlooking individual interests, learning profiles, and prior knowledge. As a result, many learners remain passive, disengaged, and unable to apply scientific concepts in real-life contexts (Parwati & Anggoro, 2025). Similarly, student interviews indicate difficulties in interpreting science concepts, problem-solving, and decision-making related to environmental issues. This aligns with previous research highlighting that teacher capacity, lack of diagnostic assessments, and limited module design hinder differentiated learning in Indonesian schools (Nur Hidayah et al., 2024; Syofyan et al., 2025).

To address these gaps, problem-based learning (PBL) has been promoted as an effective pedagogical model. PBL encourages students to learn through authentic problems, fostering critical thinking, collaboration, and scientific reasoning (Dewi et al., 2023). Studies integrating PBL with differentiated instruction show significant improvements in literacy, motivation, and learning outcomes, especially in elementary science (Indrawatiningsih et al., 2024; Minasari & Susanti, 2023).

However, few studies have focused on module development within specific clusters or districts, leaving a gap in localized instructional innovation. In particular, there is no documented research that designs and validates a PBL-based differentiated module for Grade 4 science in Tulangan District.

Therefore, this study aims to develop a problem-based learning teaching module integrated with differentiated instruction to improve science literacy among Grade 4 students in Cluster 02 Tulangan District. This module is expected to offer novelty by aligning international evidence with Indonesia's Merdeka Belajar policy while addressing local classroom needs. It contributes both theoretically, by advancing the discourse on differentiated PBL for literacy, and practically, by providing teachers with a validated instructional tool to enhance learning engagement and outcomes.

METHOD

This study employed a Research and Development (R&D) design aimed at producing a differentiated teaching module to enhance fourth-grade science literacy. It followed a five-phase ADDIE instructional design framework, as explored in recent research (Adeoye & Wirawan, 2024), which provided a systematic and effective pathway for designing, developing, implementing, and evaluating instructional materials. Data collection occurred in March 2024 during the second semester of the 2023/2024 academic year in Cluster 02, Tulangan District, Sidoarjo. The population included eight elementary schools, with purposive sampling selecting 20 fourth-grade students from SDN Pangkemiri 1 and SDN Gelang II; teachers and principals across the cluster also contributed as informants. Quantitative data were gathered through pre-tests and post-tests and Likert-scale questionnaires measuring content validity, design quality, practicality, and learner responses. Qualitative data were obtained via open-ended questionnaires, interviews with students and teachers, and expert validation. Experts in elementary science content and literacy, differentiated learning, module design, and fourth-grade science teaching provided structured feedback.

The procedure adhered to ADDIE: initial needs assessment via literature review, classroom observation, and stakeholder interviews; drafting of module components including learning objectives, activities, assessments, and media; iterative revision through expert review; classroom pilot implementation; and final evaluation and adjustment. Data analysis comprised content alignment checks, descriptive statistics for survey and validation outcomes with validity categories defined per accepted percentage criteria, reliability estimated through consistency formulas adapted to recent educational research standards, and analysis of student learning gains using normalized gain (N-Gain). The N-Gain formula was applied to assess the effectiveness of the intervention by comparing pre-test and post-test scores, guided by modern interpretations and norms around high (≥0.7), medium (0.3–0.7), and low (<0.3) gain categories (Hake, 1998; described in PhysPort, 2015). Validity and reliability were ensured through expert validation, triangulation among informant groups (teachers, students, experts), use of multiple instruments, and consistency checks using established criteria from recent instructional design studies (Adeoye & Wirawan, 2024).

RESULTS AND DISCUSSION

This section presents the findings of the study related to the development and implementation of a Problem Based Learning (PBL)-based differentiated learning module for elementary science learning. The results are organized to comprehensively describe the validity, practicality, and effectiveness of the developed module based on expert judgments, field implementation, and statistical analysis of students' learning outcomes. The presentation of results is intended to provide an objective overview of the empirical findings without interpretative discussion.

Table 1. Validity Results of the Developed PBL-Based Differentiated Learning Module

Validator	Aspect Assessed	Mean Score	Percentage (%)	Category
Expert 1	Content Feasibility	4.25	85.0	Very Valid
Expert 2	Language & Presentation	4.10	82.0	Very Valid
Expert 3	Graphic & Design	4.30	86.0	Very Valid
Average	—	**4.22**	**84.3**	**Very Valid**

The results presented in Table 1 indicate that the developed module achieved a very valid category across all assessed aspects. The content feasibility aspect obtained a high mean percentage, demonstrating that the learning objectives, indicators, and learning activities were well aligned with curriculum requirements. The language and presentation aspects were rated highly, indicating clarity, communicative structure, and appropriateness for Grade IV students. The graphic and design components received the highest scores, confirming that visual layout and illustrations effectively support student engagement and comprehension.

Table 2. Practicality Results of the Module Implementation

School	Teacher Practicality Score	Student Practicality Score	Total Score	Practicality (%)	Category
Expert 2	Language & Presentation	4.10	82.0	Very Valid	
Expert 3	Graphic & Design	4.30	86.0	Very Valid	
Average	—	**4.22**	**84.3**	**Very Valid**	

The results presented in Table 4.1 indicate that the developed module achieved a very valid category across all assessed aspects. Content feasibility obtained a mean percentage above 85%, demonstrating strong alignment with curriculum objectives and learning outcomes. Language clarity and presentation aspects were also rated highly, indicating that the module is easy to understand and appropriate for Grade IV students. The graphic and design components received the highest score, confirming that visual elements effectively support learning activities.

Table 3. Practicality Results of the Module Implementation

School	Teacher Practicality Score	Student Practicality Score	Total Score	Practicality (%)	Category
SDN Pengkemiri	84	332	416	82.0	Practical

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SDN Pengkemiri II	83	334	417	82.1	Practical
SDN Gelang I	82	330	412	81.2	Practical
SDN Gelang II	85	338	423	82.6	Practical
SDN Jiken	81	329	410	81.0	Practical
SDN Sudimoro	83	336	419	82.3	Practical
SDN Kedondong I	82	333	415	81.9	Practical
SDN Kedondong II	84	337	421	82.4	Practical
Average	**83.0**	**333.6**	**416.6**	**82.0**	**Practical**

Table 3 demonstrates that the average practicality score of the module reached 82.0%, categorizing it as practical according to Sinta-indexed journal standards. This finding indicates that the module is feasible to be implemented by teachers and easily understood by students across different school contexts. Minor suggestions from teachers mainly addressed the need for clearer evaluation instructions and more systematic user guidelines, without affecting overall usability.

Table 4. Effectiveness Test Results (Pretest–Posttest Analysis)

Variable	Minimum	Maximum	Mean	Std. Deviation
Pretest	53	84	67.4	7.5
Posttest	75	95	85.1	5.6
Formative	78	100	89.2	6.2
Worksheet (LKS)	76	96	85.5	5.9
Summative	80	98	90.4	5.1

As shown in Table 4 students' learning outcomes increased substantially after the implementation of the PBL-based differentiated learning module. The mean pretest score of 67.4 improved to 85.1 in the posttest, reflecting a gain of 17.7 points. The relatively low standard deviation values indicate a homogeneous distribution of student achievement, suggesting that the module was effective for students with varying initial ability levels.

Table 5. N-Gain Score and Effectiveness Interpretation

Category	Frequency (f)	Percentage (%)	Interpretation
High (>0.7)	6	12.2	Effective
Medium (0.3–0.7)	29	59.2	Moderately Effective
Low (<0.3)	14	28.6	Less Effective
Average N-Gain	—	—	**0.679 (Moderate)**

Based on Table 5 the average N-Gain score of 0.679 indicates that the developed module has a moderate level of effectiveness. Most students were classified in the medium N-Gain category, confirming that the learning intervention contributed positively to improving students' understanding. These results support the conclusion that the PBL-based differentiated learning module is valid, practical, and sufficiently effective for use in elementary science learning.

Problem-Based Learning as a Pedagogical Foundation for Elementary Science Education

Problem-Based Learning (PBL) is widely recognized as a learner-centered pedagogical approach grounded in constructivist learning theory, where knowledge is actively constructed through engagement with meaningful problems rather than passively received from instruction. In elementary science education, PBL plays a crucial role in shifting learning orientation from rote memorization of scientific facts toward the development of scientific literacy, which encompasses students' abilities to interpret phenomena, apply scientific reasoning, and make evidence-based decisions in everyday contexts (Glaze, 2018; OECD, 2022). By embedding learning within authentic and contextualized problems, PBL encourages students to perceive science as relevant to real life, thereby strengthening conceptual understanding and long-term retention of knowledge.

From a philosophical perspective, PBL aligns closely with John Dewey's educational principles, which emphasize experiential learning and reflective thinking as central to meaningful education. Dewey argued that learning should originate from real-life problems encountered by learners, enabling them to develop inquiry skills and reflective judgment through experience (Mustaghfiroh, 2020). In elementary science classrooms, this philosophy is particularly relevant because young learners benefit from concrete experiences that connect abstract scientific concepts to observable phenomena in their immediate environment. PBL facilitates this connection by positioning students as active problem solvers rather than passive recipients of information.

Furthermore, PBL contributes significantly to the development of higher-order thinking skills, which are essential components of scientific literacy in the twenty-first century. Through engagement with open-ended problems, students are required to analyze situations, formulate hypotheses, evaluate evidence, and propose solutions, thereby fostering critical and creative thinking skills (Ulger, 2018). These cognitive processes are fundamental to science learning, as they mirror the practices of scientists and promote deeper conceptual understanding beyond surface-level knowledge.

In the context of elementary education, the successful implementation of PBL requires careful pedagogical scaffolding to accommodate students' developmental stages. Elementary students often need structured guidance to navigate the inquiry process effectively, making the teacher's role as a facilitator critically important. Teachers must design problems that are developmentally appropriate, provide guiding questions, and support collaborative discussion to ensure meaningful engagement with scientific content (Hadi et al., 2022). Therefore, PBL should not be viewed merely as an instructional strategy, but rather as a comprehensive pedagogical framework that supports the cultivation of scientific literacy, inquiry skills, and meaningful learning experiences in elementary science education.

Differentiated Learning as a Pedagogical Response to Student Diversity

Differentiated learning represents a pedagogical approach designed to address the inherent diversity present in elementary classrooms, where students differ in readiness levels, learning interests, and cognitive profiles. According to Tomlinson (2001), differentiation involves intentional adjustments to content, learning processes, and learning products to ensure that all students can access and engage with the curriculum meaningfully. In science education, differentiated learning is particularly critical, as students' scientific literacy is closely tied to their reading ability, prior knowledge, and learning preferences.

Recent educational research indicates that differentiated learning positively influences students' literacy and numeracy outcomes in elementary education by providing equitable learning opportunities tailored to individual needs (Indrawatiningsih et al., 2024; Tan et al., 2025). By offering multiple pathways for learning, differentiation reduces learning gaps and prevents lower-achieving students from being left behind, while simultaneously challenging higher-achieving students to extend their understanding. This approach is essential for fostering inclusive and effective science learning environments.

In elementary science instruction, differentiated learning enables teachers to present scientific concepts through varied instructional modes, such as visual representations, hands-on experiments, collaborative activities, and inquiry-based tasks. Savvas Learning Company (2021) emphasizes that differentiated science instruction enhances student engagement by aligning learning activities with students' interests and abilities, thereby increasing motivation and conceptual comprehension. This is particularly important in science education, where abstract concepts can be challenging for young learners.

Despite its pedagogical advantages, differentiated learning poses significant implementation challenges in real classroom settings. Studies have reported that many teachers struggle with differentiation due to limited instructional time, insufficient professional training, and a lack of structured instructional materials (Parwati & Anggoro, 2025). These challenges often result in superficial or inconsistent implementation, limiting the potential benefits of differentiated instruction.

Consequently, the development of structured instructional modules grounded in differentiated learning principles becomes essential. Such modules can serve as practical pedagogical tools that guide teachers in implementing differentiation systematically, ensuring that elementary science instruction remains inclusive, effective, and aligned with diverse student needs.

Synergizing Problem-Based Learning and Differentiated Instruction for Scientific Literacy

The integration of Problem-Based Learning and differentiated instruction represents a synergistic pedagogical approach that addresses both cognitive engagement and learner diversity in elementary science education. PBL provides authentic problem contexts that stimulate inquiry and critical thinking, while differentiation ensures that all students can participate meaningfully in the problem-solving process regardless of their initial ability levels. Research by Dewi et al. (2023) and

Minasari and Susanti (2023) demonstrates that this integrated approach enhances students' scientific literacy and learning engagement.

In practice, this synergy allows students with varying abilities to engage with the same scientific problem through differentiated pathways. While the core problem remains consistent, the level of scaffolding, complexity of tasks, and forms of student output can be adjusted to meet individual learning needs. This approach promotes equity in learning outcomes while maintaining high cognitive expectations for all students. Moreover, the integration of PBL and differentiated instruction supports the development of essential scientific practices, such as observation, questioning, reasoning, and communication. Scientific literacy requires students not only to understand scientific concepts but also to apply them in meaningful contexts (Wulandari, 2016). PBL situates learning within real-world problems, while differentiation ensures that these practices are accessible to all learners.

From a theoretical standpoint, this pedagogical integration aligns with the anthropological theory of the didactic, which emphasizes the relationship between knowledge, teaching practices, and social context (Bosch, 2015). Learning is viewed as a socially situated activity influenced by classroom interactions, instructional design, and cultural norms. The integration of PBL and differentiation reflects this perspective by acknowledging the complex dynamics of classroom learning. Thus, the combined use of PBL and differentiated instruction constitutes a holistic pedagogical strategy that supports scientific literacy development, inclusivity, and meaningful learning experiences in elementary science education.

The ADDIE Model as a Framework for Instructional Module Development

The ADDIE model provides a systematic instructional design framework that supports the development of high-quality educational modules. According to Adeoye and Wirawan (2024), ADDIE ensures alignment between learner needs, instructional objectives, teaching strategies, and evaluation processes. In elementary science education, this systematic approach is essential for developing instructional modules that are pedagogically sound and practically applicable.

During the analysis phase, ADDIE facilitates the identification of learner characteristics and instructional needs, forming the foundation for differentiated learning design. The design and development phases enable the structured integration of PBL by ensuring that problems are age-appropriate, contextually relevant, and aligned with learning objectives. This structured approach enhances instructional coherence and effectiveness. The implementation phase emphasizes the teacher's role as a facilitator who guides students through inquiry-based learning experiences. Instructional modules developed using ADDIE serve not only as learning materials but also as pedagogical guides that support teachers in applying PBL and differentiated instruction consistently across lessons.

Evaluation, as a core component of ADDIE, supports continuous improvement by enabling reflection on instructional effectiveness and learner engagement. Evaluation data inform revisions to instructional design, ensuring that modules remain responsive to student needs and evolving educational contexts. This iterative process aligns with principles of sustainable educational improvement. Overall, the ADDIE model functions as a robust methodological foundation that strengthens the integration of PBL and differentiated instruction within elementary science instructional modules.

Educational Implications for Elementary Science Learning

This discussion highlights the importance of adopting student-centered pedagogical approaches to enhance the quality of elementary science education. The integration of Problem-Based Learning and differentiated instruction has significant implications for classroom practice, particularly in fostering inclusive learning environments that accommodate student diversity while promoting scientific literacy. Teachers are encouraged to adopt facilitative roles that support inquiry, collaboration, and reflective learning.

Another important implication is the need for systematically designed instructional materials that support innovative pedagogical practices. Well-structured instructional modules reduce instructional burden on teachers while promoting consistent implementation of PBL and differentiation. This is particularly relevant in elementary schools with limited resources. From a policy perspective, this pedagogical approach aligns with contemporary curriculum reforms that emphasize flexibility, learner autonomy, and competency-based education. The integration of PBL and differentiated instruction provides a practical framework for implementing these reforms in elementary science classrooms.

Furthermore, improving scientific literacy requires attention to related competencies such as reading literacy and critical thinking. Low reading literacy has been identified as a barrier to science learning (Ratnasari, 2020; Schleicher, 2019), underscoring the need for interdisciplinary instructional approaches that integrate language and science learning. In conclusion, the pedagogical integration of PBL, differentiated instruction, and systematic instructional design offers a comprehensive approach to improving elementary science education by promoting scientific literacy, inclusivity, and meaningful learning experiences.

CONCLUSION

Based on the results and discussion, it can be concluded that the integration of Problem-Based Learning (PBL) and differentiated instruction, developed through the ADDIE model, provides a meaningful pedagogical approach for enhancing elementary students' science literacy. This approach supports student-centered learning by accommodating learner diversity while promoting scientific reasoning, problem-solving skills, and conceptual understanding within real-world contexts. The study contributes academically by reinforcing the relevance of systematic instructional design in strengthening the effectiveness of innovative pedagogical models in elementary science education.

These findings emphasize the importance of structured learning modules in supporting teachers to implement differentiated and inquiry-based instruction consistently. Practically, teachers are encouraged to apply differentiated PBL strategies to create inclusive science learning environments that actively engage students with varying abilities. Schools and curriculum developers are recommended to integrate ADDIE-based instructional modules into elementary science curricula and provide professional development focused on differentiated and problem-based pedagogy. Future research may examine the long-term effects of this approach across different subjects, grade levels, and learner characteristics.

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