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Teacher Professional Development in Science: Planning Deep Learning Based on the LABIRIN

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Abstract

The Indonesian government has encouraged the integration of deep learning principles into creative and innovative instructional designs to strengthen meaningful, mindful, and joyful learning. In this study, deep learning refers to an educational approach emphasizing mindful, meaningful, and joyful learning, rather than the deep-learning technology used in artificial intelligence. This study aims to examine and describe science teachers' professional development in planning deep learning based on the LABIRIN framework. A qualitative approach with a case study design was employed. The participants were 40 science teachers from Jakarta, Depok, Bogor, Bekasi, and Tangerang. Data were collected through triangulation involving in-depth interviews, participant observations, and document analysis. The findings show how teachers developed their capacity to plan deep learning through the LABIRIN framework. First, teachers developed an understanding of the conceptual relationship between the deep learning framework and the LABIRIN framework. Second, through intensive professional guidance, teachers gradually connected the dimensions of deep learning with the corresponding LABIRIN dimensions. This process enabled them to align learning objectives, assessment strategies, and teaching and learning activities more systematically. However, some teachers continued to experience difficulties in translating the framework into concrete learning activities, indicating variation in the development of planning competence. Overall, the findings suggest that structured professional development and intensive guidance supported teachers in developing their capacity to translate the LABIRIN framework into coherent deep learning plans in diverse educational contexts. The study highlights the importance of framework-based teacher professional development in supporting the effective implementation of deep learning in science education.

Keywords: Deep learning; LABIRIN framework; Instructional planning; Science.

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INTRODUCTION

Indonesia has introduced deep learning as a pedagogical approach in early childhood, primary, and secondary education through Permendikdasmen Number 13 of 2025. This policy emphasizes that deep learning complements existing curricula, including the Merdeka Curriculum and the 2013 Curriculum, rather than replacing them (Kemendikbudristek, 2022). In this context, deep learning promotes mindful, meaningful, and joyful learning experiences that encourage students to construct knowledge, develop conceptual understanding, and actively engage in learning (Wathon, 2025). From a broader educational perspective, deep learning emphasizes intellectual engagement, knowledge integration, and higher-order thinking rather than passive information acquisition (Biggs, 1989; Fullan et al., 2018). In science education, deeper learning also involves connecting scientific knowledge with students' curiosity and engagement in scientific phenomena (Otto et al., 2020). These perspectives

suggest that deep learning requires instructional practices that integrate cognitive engagement, meaningful experiences, and transferable competencies.

The implementation of deep learning is closely related to Indonesia's efforts to improve educational quality. The Programme for International Student Assessment (PISA) indicates that Indonesian students' performance in mathematics, reading, and science remains below the OECD average (OECD, 2023). Although these results do not establish the effectiveness of any particular pedagogical approach, they highlight the need to strengthen conceptual understanding, critical thinking, and problem-solving abilities. Meaningful learning encourages students to connect prior knowledge with new concepts and learning experiences, while collaborative activities support knowledge construction (Sharan, 2015). Student engagement also involves behavioral, emotional, and cognitive dimensions that influence participation and learning processes (Fredricks et al., 2004). The Interactive, Constructive, Active, and Passive (ICAP) framework further emphasizes that constructive and interactive engagement can provide stronger learning opportunities than passive participation (Chi & Wylie, 2014). Therefore, deep learning requires purposeful instructional designs that encourage reflection, inquiry, and conceptual integration. Furthermore, digital literacy has become increasingly relevant as education responds to technological developments and changing societal demands (Hidayat & Lestari, 2025).

However, implementing deep learning depends substantially on teachers' professional understanding and instructional competence. Teachers must move beyond transmitting knowledge toward facilitating students' active construction of understanding (Hendrianty et al., 2024). This transformation requires teachers to understand pedagogical principles and translate them into coherent learning objectives, assessment strategies, and instructional activities. Research on teacher professional development identifies content focus, active learning, and coherence with professional practice as important characteristics of effective programs (Garet et al., 2001). Desimone (2009) emphasizes the importance of examining how professional learning contributes to teachers' knowledge and instructional practices. Similarly, Darling-Hammond et al. (2017) identify collaboration, modeling, coaching, feedback, reflection, and sustained learning opportunities as essential features of effective professional development. These perspectives suggest that theoretical explanations alone are insufficient to develop instructional planning competence. Teachers also need opportunities to design, evaluate, and revise learning activities. Backward-design principles offer a relevant foundation by emphasizing alignment among intended learning outcomes, assessment evidence, and instructional experiences (Wiggins & McTighe, 2005).

Professional development is particularly important in science education because effective science instruction requires the integration of disciplinary knowledge, pedagogical competence, and scientific inquiry. Teachers' competencies significantly influence instructional quality and student learning outcomes (Fauth et al., 2019; Onipede et al., 2025). Science education requires students to understand concepts while engaging in observation, investigation, experimentation, reasoning, and evidence-based explanation. The National Research Council (2012) emphasizes the integration of scientific practices, crosscutting concepts, and disciplinary core ideas in meaningful science learning. Science-process skills, including observation, classification, prediction, experimentation, interpretation, and communication, are also essential for developing scientific understanding (Gizaw & Sota, 2023). Inquiry-based learning supports students in investigating questions and constructing explanations through evidence (Owolade et al., 2022), while problem-based learning encourages knowledge construction and independent problem-solving (Hmelo-Silver, 2004). In Chemistry and Biology, practical and pedagogical competencies are particularly relevant for connecting abstract scientific concepts with contextual experimental experiences (Handayani & Azzahra, 2024). Therefore, teachers must select appropriate instructional models and organize meaningful learning experiences. Systematic instructional models provide guidance

for structuring teaching and learning processes (Joyce et al., 2015).

The importance of professional development was also reflected in the preliminary findings of this study. Interviews with 40 teachers teaching Natural Sciences, Physics, Chemistry, and Biology indicated that 98% reported encountering the educational concept of deep learning for the first time. Several participants initially associated deep learning with active student participation and considered it similar to previously implemented learning approaches. These findings suggest that familiarity with student-centered instruction does not necessarily indicate an integrated understanding of deep learning. Teachers may recognize individual pedagogical principles but experience difficulties translating them into systematic instructional plans. In particular, connecting graduate-profile dimensions, learning objectives, assessment strategies, and learning activities requires competencies beyond conceptual familiarity. Consequently, professional development should provide opportunities for teachers to explore the relationships among these components and develop coherent instructional planning practices.

In addition to understanding deep learning, science teachers require an adequate understanding of the nature of science (NOS). NOS concerns the characteristics of scientific knowledge, scientific inquiry, evidence, and the processes through which scientific explanations are developed. Understanding these epistemological foundations is important for designing learning experiences that reflect authentic scientific practices (Lederman, 2007). Scientific explanation and inquiry also encourage students to develop reasoning abilities and examine how scientific knowledge is constructed (Tschaepe, 2012). A preliminary NOS assessment administered to the 40 participating teachers indicated that 90% demonstrated an understanding of NOS and its relationship to learning outcomes within the Merdeka Curriculum, while 10% did not. Although most participants demonstrated relevant foundational knowledge, this finding does not necessarily indicate that they consistently incorporated NOS into their instructional plans. Therefore, professional development should strengthen connections between teachers' understanding of scientific knowledge and their ability to design inquiry-oriented learning experiences.

One potential framework for supporting this process is LABIRIN (Exciting, Interactive, and Unique Learning), developed within the Faculty of Teacher Training and Education at Universitas Katolik Parahyangan. LABIRIN consists of three interconnected dimensions intended to support flexible and contextual instructional planning. The exciting dimension emphasizes intellectual engagement and active participation through meaningful thinking and movement. The interactive dimension emphasizes relationships between humans and God, among humans, and between humans and nature. The unique dimension encourages creative, distinctive, and contextually responsive learning experiences. These dimensions can be adapted to monodisciplinary and multidisciplinary contexts, including science education. Research on deeper learning in science highlights the potential of creative and participatory activities for supporting meaningful engagement (Kotsari & Smyrnaiou, 2021). Similarly, classroom environments and instructional approaches that encourage active participation can contribute to deeper engagement with learning content (Paleenud et al., 2024). These perspectives provide conceptual support for selected characteristics of LABIRIN, although they do not independently establish its empirical validity. Therefore, LABIRIN requires further investigation regarding its theoretical foundations, practical application, and contribution to instructional planning.

The relationship between LABIRIN and deep learning can be understood as complementary rather than equivalent. Deep learning provides a broader pedagogical orientation through four interconnected components: the graduate profile, learning principles, learning experiences, and learning framework. LABIRIN offers dimensions through which teachers may translate these components into contextual instructional activities. The exciting dimension can encourage cognitive engagement and purposeful participation, while the

interactive dimension supports collaboration, communication, and meaningful relationships with the surrounding environment. The unique dimension provides opportunities to adapt activities to scientific concepts, student characteristics, and educational contexts. Through this integration, teachers may develop instructional plans that connect conceptual understanding, scientific inquiry, reflection, creativity, and student interaction. However, integrating these frameworks requires careful distinctions among intended learning outcomes, cognitive processes, and instructional activities. The revised taxonomy of educational objectives provides a relevant conceptual reference for understanding knowledge dimensions and cognitive processes in instructional planning (Anderson & Krathwohl, 2014). Thus, LABIRIN is positioned in this study as a potential framework for operationalizing deep learning principles rather than as a previously validated model of instructional effectiveness.

Despite increasing attention to deep learning and teacher professional development, limited empirical evidence is available concerning how science teachers develop instructional planning competence by integrating deep learning with LABIRIN. Previous research has examined deeper learning, student engagement, scientific inquiry, and the characteristics of effective professional development. However, these studies do not directly explain how teachers interpret the relationships between deep learning components and LABIRIN dimensions during instructional planning. In particular, further investigation is needed to understand how teachers translate conceptual knowledge into learning objectives, assessment strategies, instructional activities, and reflection opportunities. Examining this process is important because understanding pedagogical terminology does not automatically ensure the ability to design coherent learning experiences. The research gap therefore concerns the development of teachers' planning competence and the challenges associated with integrating multiple pedagogical dimensions into meaningful science instructional designs. Investigating this gap may provide insights into how structured professional development supports teachers' emerging instructional planning practices and identifies areas requiring further guidance.

Therefore, this study aims to analyze and describe how Natural Sciences, Chemistry, Physics, and Biology teachers develop their capacity to plan deep learning based on the LABIRIN framework. Specifically, the study examines teachers' understanding of deep learning components, their interpretation of relationships between deep learning and LABIRIN dimensions, and the challenges encountered when translating these relationships into instructional plans. Using a qualitative embedded case study, the investigation focuses on teachers' professional learning experiences and instructional planning practices rather than establishing causal effects of professional development. The study is expected to contribute empirical insights into framework-based teacher professional development and provide practical considerations for designing contextual, interactive, and inquiry-oriented science learning. Its findings may inform schools, educational institutions, teachers, and researchers seeking to strengthen instructional planning through the integration of deep learning principles and LABIRIN.

METHOD

Research Design

This study employed a qualitative approach using a single embedded case study design grounded in social constructivism, which emphasizes that individuals construct knowledge and meaning through their experiences and social interactions (Creswell & Poth, 2018). This approach was selected to explore how science teachers understood, interpreted, and translated deep learning principles into instructional planning practices through the LABIRIN framework. The case study design enabled an in-depth examination of teachers' professional learning experiences, instructional planning processes, and challenges within a specific professional development context (Yin, 2018).

The bounded case was a professional development program focusing on the integration of deep learning principles with the LABIRIN framework. The case was defined by the

program's objectives, participating teachers, eight-week implementation period, and instructional planning activities. Individual teachers served as embedded units of analysis, while three interconnected analytical domains guided the investigation: (1) teachers' understanding of deep learning principles and components, (2) their understanding of the nature of science and its implications for science instruction, and (3) their ability to integrate deep learning components with the exciting, interactive, and unique dimensions of LABIRIN. These analytical domains were examined within and across participants to identify recurring patterns, variations, and challenges in professional learning.

The study was conducted over six months beginning in January 2026, encompassing research preparation, implementation, data collection, and qualitative analysis. The professional development program consisted of eight sessions conducted over eight weeks using a flipped classroom approach, with approximately five hours allocated to each session. The program emphasized conceptual understanding of deep learning and its application to science instructional planning through LABIRIN. Distinguishing the eight-week professional development period from the six-month research period clarified the temporal boundaries of the case and the broader research activities.

Participants

The participants consisted of 40 teachers of Natural Sciences (IPA), Chemistry, Physics, and Biology representing early childhood education (PAUD), elementary education, and secondary education. They were recruited from Jakarta, Depok, Bogor, Bekasi, and Tangerang, Indonesia. Purposive sampling was employed to select participants whose teaching responsibilities and professional learning experiences were relevant to the research objectives. This sampling strategy was consistent with qualitative research principles, which emphasize selecting information-rich participants capable of providing meaningful insights into the phenomenon under investigation (Creswell & Poth, 2018).

Participants were selected based on three inclusion criteria: (1) actively teaching science or science-related subjects at their respective educational levels; (2) participating in the complete professional development program; and (3) being willing to provide instructional planning documents and participate in research activities. These criteria ensured that the participants had direct experience with the program and could contribute relevant evidence concerning the development of LABIRIN-based instructional planning practices.

All participants provided informed consent before participating in the research. Participation was voluntary, and participants were informed about the research objectives, data collection procedures, and intended use of their responses and instructional planning documents. Confidentiality was maintained by excluding personally identifying information from the reported findings. The study sought to understand professional learning within the bounded case rather than generate statistically generalizable conclusions about science teachers in Indonesia.

Instruments and Data Collection

Data were collected through three complementary techniques: in-depth interviews, participant observations, and document analysis. These techniques were employed to obtain evidence concerning teachers' conceptual understanding, professional learning experiences, interactions, and instructional planning practices. The use of multiple sources of evidence was consistent with case study research principles, which emphasize examining a phenomenon through different forms of evidence to develop a comprehensive and contextually grounded interpretation (Yin, 2018).

In-depth interviews were conducted to explore teachers' understanding and interpretations of deep learning, the nature of science, and the LABIRIN framework. The interviews focused on how participants understood the relationships among deep learning components, interpreted the exciting, interactive, and unique dimensions of LABIRIN, and

experienced challenges in translating these concepts into instructional plans. Interview data also provided insights into participants' perceptions of their professional learning and the difficulties encountered during instructional planning activities.

Participant observations were conducted throughout the professional development sessions to examine teachers' engagement, interactions, and learning processes. Observations focused on teachers' participation in professional learning activities, their discussions of instructional planning concepts, their responses to feedback, and their attempts to connect deep learning principles with LABIRIN dimensions. Observation evidence was used to contextualize interview findings and examine how teachers' understanding was expressed during professional learning activities.

Document analysis focused on instructional planning materials developed and revised by participants during the program. These documents included initial learning-plan drafts and subsequent revisions. The analysis examined how teachers represented the four components of deep learning, namely the graduate profile, learning principles, learning experiences, and learning framework, and how these components were connected to the three LABIRIN dimensions of exciting, interactive, and unique learning. Particular attention was given to the alignment among intended learning outcomes, instructional activities, assessment strategies, and the contextual characteristics of science learning. Comparing initial and revised instructional plans provided evidence of developments and persistent challenges in teachers' instructional planning practices.

The three data sources were examined as complementary forms of evidence. Interviews provided information about teachers' reported understanding and perceived challenges, observations documented their interactions and participation during professional learning, and instructional planning documents provided tangible evidence of their planning decisions. Integrating these sources supported methodological triangulation and enabled a more comprehensive examination of teachers' professional learning experiences and instructional planning practices (Creswell & Creswell, 2018; Yin, 2018).

Data Analysis

Data were analyzed qualitatively through an iterative process involving initial coding, categorization, thematic synthesis, and comparison across embedded units of analysis. The analytical procedure was informed by Yin's (2018) case study approach, particularly within-unit analysis, cross-unit synthesis, pattern matching, and the integration of multiple sources of evidence. The analysis combined inductive identification of emerging themes with theoretically informed interpretation based on the deep learning components and LABIRIN dimensions.

First, within-unit analysis was conducted to examine individual teachers' understanding, experiences, and instructional planning practices. Interview transcripts, observation notes, and instructional planning documents were reviewed to identify meaningful statements and evidence related to participants' conceptual understanding, interpretation of instructional frameworks, planning decisions, and perceived challenges. Initial codes were generated from the data and subsequently grouped into categories representing similar meanings, experiences, and instructional planning practices. These categories were then synthesized into broader themes relevant to the research objectives.

Second, cross-unit analysis was undertaken to identify similarities, differences, and recurring patterns across participants. The analysis examined variations in teachers' understanding of deep learning principles, their interpretation of the nature of science, and their ability to integrate deep learning components with the LABIRIN framework. Particular attention was given to convergent and divergent evidence, including instances in which teachers demonstrated conceptual understanding but continued to experience difficulties translating that understanding into coherent instructional activities. This comparative analysis supported a nuanced interpretation of professional learning and reduced the risk of treating

individual experiences as representative of all participants.

Third, pattern matching was used to compare empirical findings with the conceptual structures of deep learning and LABIRIN. The analysis considered four interconnected components of deep learning: (1) graduate profile, (2) learning principles, (3) learning experiences, and (4) learning framework. These components were examined in relation to the exciting, interactive, and unique dimensions of LABIRIN. The analysis specifically investigated how teachers translated these conceptual components into instructional planning decisions, including the selection of learning objectives, assessment strategies, instructional activities, and contextual science learning experiences.

Fourth, methodological triangulation was conducted by comparing evidence obtained from interviews, observations, and instructional planning documents. Teachers' reported understanding of deep learning principles was examined alongside their engagement during professional development activities and the instructional decisions represented in their learning plans. Convergent evidence was used to strengthen interpretations, while discrepancies among data sources were retained and examined to identify variations and complexities in teachers' professional learning. This approach supported a more balanced interpretation of teachers' developing instructional planning practices.

Finally, a holistic case analysis was conducted to integrate findings from individual participants into an overall interpretation of the professional development program. The synthesis focused on identifying emerging developments in teachers' instructional planning, recurring difficulties, and areas requiring further professional support. Particular attention was given to distinguishing teachers' reported changes in understanding from developments demonstrated through their instructional planning documents.

The analytical process was guided by methodological coherence between the research objectives, social constructivist perspective, and qualitative case study design (Creswell & Poth, 2018). An audit trail was maintained to document the coding process, development of categories and themes, and interpretation of findings. Reflexive consideration was also given to the researchers' roles within the professional development context and their potential influence on data collection and interpretation. Data collection and analysis were conducted iteratively, with attention to recurring patterns, divergent experiences, and the adequacy of evidence supporting the emerging themes.

The findings were interpreted within the contextual boundaries of the case study. Changes identified through interviews, observations, and instructional planning documents were understood as evidence of developing professional understanding and instructional planning practices rather than definitive proof of a causal effect of the professional development program. This interpretation was consistent with the qualitative purpose of examining how teachers understood, negotiated, and operationalized deep learning principles through the LABIRIN framework.

RESULTS AND DISCUSSION

The results and discussion focus on the integration of deep learning with the LABIRIN framework in science learning. In this study, deep learning is conceptualized through four main components: (1) the graduate profile, (2) learning principles, (3) learning experiences, and (4) the learning framework. These components are integrated with the three dimensions of LABIRIN: (1) exciting, (2) interactive, and (3) unique. The exciting dimension encompasses two elements, namely the enjoyment of thinking and the enjoyment of movement. The interactive dimension comprises three elements that emphasize balance in relationships: the relationship between humans and God, among humans, and between humans and nature. The unique dimension provides opportunities for teachers to develop distinctive, contextual, and creative learning experiences. The integration of these components and dimensions provides the basis for examining how teachers plan deep learning through the LABIRIN framework.

Graduate Profile

Before the professional development, teachers demonstrated a basic understanding of the graduate profile within the deep learning framework. Interview findings indicated that teachers recognized that the graduate profile differed from the previous Pancasila Student Profile and were able to identify the eight dimensions stipulated by the Ministry of Education (2025): faith and piety toward God Almighty, citizenship, critical reasoning, creativity, collaboration, independence, health, and communication. This initial familiarity indicates that teachers possessed knowledge of the policy terminology, although their ability to translate these dimensions into coherent instructional planning remained an important area of investigation.

Following the professional development, teachers reported a broader appreciation of the comprehensiveness of the Indonesian graduate profile. They recognized that several dimensions correspond with competencies emphasized in international education frameworks. Fullan et al. (2018), for example, identifies character, citizenship, collaboration, communication, creativity, and critical thinking as important global competencies. The Indonesian framework extends this orientation by explicitly incorporating health and faith and piety toward God Almighty. One teacher stated,

> *"I just realized that our curriculum is more complete than the global curriculum based on Fullan's theory. I became motivated to teach my students to compete in the global world".*

This statement illustrates the teacher's interpretation of the graduate profile and its perceived relevance to broader educational competencies. However, the quotation represents a reported change in understanding and motivation rather than direct evidence of improved instructional competence. The significance of this finding therefore lies in the teacher's emerging ability to connect national educational expectations with the purposes of instructional planning.

Analysis of the learning-plan documents showed that teachers did not incorporate all eight graduate-profile dimensions into every learning design. Instead, four dimensions—critical reasoning, collaboration, communication, and independence—appeared most frequently across PAUD, primary, and secondary education. Critical reasoning was the most consistently represented dimension, with indicators generally related to higher-order thinking, such as analyzing issues arising from problems, evaluating information, and justifying decisions using logical arguments.

The selective representation of graduate-profile dimensions should not automatically be interpreted as incomplete implementation. Instead, it may indicate that teachers prioritized competencies they considered most relevant to specific learning objectives and activities. This interpretation is consistent with the principle that instructional decisions should be guided by intended learning outcomes and the evidence required to demonstrate their achievement (Wiggins & McTighe, 2005). The revised taxonomy of educational objectives also provides a conceptual basis for distinguishing cognitive processes and knowledge dimensions when formulating instructional objectives (Anderson & Krathwohl, 2014).

The strong emphasis on critical reasoning is consistent with the broader conception of deep learning as involving higher-order cognitive processes. Biggs (1989) associated deep learning with processes such as analysis, synthesis, and evaluation, while Dai (2023) emphasized critical thinking, creativity, and problem-solving as important characteristics of deeper learning. Within science education, critical reasoning also supports students' ability to examine evidence, construct explanations, and communicate scientific arguments. Amin et al. (2023) discuss the relationship between communication, digital literacy, and critical thinking, providing a relevant perspective on the interconnected competencies represented in teachers' learning plans.

Nevertheless, the document evidence also indicates that cognitive alignment was more

readily operationalized than some other graduate-profile dimensions. Interview data further showed that teachers often selected graduate-profile dimensions after determining the learning activities they intended to conduct. This pattern reveals a distinction between knowing the intended graduate competencies and using them as the starting point for instructional design. Some teachers continued to follow an activity-oriented planning sequence, in which activities were identified before their intended outcomes and assessment evidence were considered.

Such planning practices differ from backward design, which begins by identifying desired results, determining acceptable evidence, and subsequently designing instructional experiences (Wiggins & McTighe, 2005). Research examining the quality of science teachers' lesson plans also highlights the importance of transparent criteria for evaluating instructional planning decisions (Großmann & Krüger, 2024). Accordingly, the present finding suggests that professional development should provide more opportunities for teachers to examine the alignment among graduate-profile dimensions, learning objectives, assessment, and learning activities.

The graduate profile was also related to the exciting dimension of LABIRIN, particularly through the elements of thinking and moving. Before the professional development, teachers generally considered the learning outcomes established by the Ministry of Education (2025). In science-related subjects, these outcomes included conceptual understanding and process skills. However, interview and document evidence indicated that conceptual understanding received greater attention than science-process skills.

Following the professional development, teachers' learning plans demonstrated greater attention to connecting conceptual understanding with science-process skills. The revised learning plans became more contextual and included activities connected to students' everyday experiences. This development is pedagogically relevant because scientific understanding involves not only acquiring concepts but also engaging in activities through which students investigate and interpret natural phenomena. This orientation is consistent with science education approaches that emphasize the analysis of natural phenomena and the application of scientific concepts to authentic problems (Wisudawati & Sulistyowati, 2026). One teacher explained,

> *"I just realized that the success of students in learning science is not only mastering concepts but making students actively build their own knowledge. I also became enthusiastic in designing this learning because I was challenged to design activities that students would do".*

The statement indicates a reported shift from emphasizing conceptual mastery toward recognizing students' active involvement in constructing scientific understanding. Document analysis provided complementary evidence through learning activities requiring students to analyze information, develop conceptual representations, and respond to guiding questions. These activities reflect the thinking element of LABIRIN's exciting dimension, in which intellectual engagement is emphasized rather than entertainment alone.

The moving element was reflected in science-process activities, including observing ant behavior in response to different types of sugar, conducting activities involving transparent and bouncing eggs, and observing a spiral paper model moving above a candle. These activities provided opportunities for teachers to connect physical engagement with observation, experimentation, and scientific explanation. The pedagogical significance of movement therefore depends on whether the activity supports the investigation and interpretation of scientific phenomena. Research on inquiry-based science education similarly emphasizes the importance of connecting conceptual, procedural, and pedagogical dimensions of scientific inquiry (Strata et al., 2024).

Overall, the findings indicate emerging development in teachers' capacity to connect graduate-profile dimensions, critical reasoning, conceptual understanding, and science-process

skills with the exciting dimension of LABIRIN. Nevertheless, conceptual understanding and instructional planning competence did not develop uniformly. The evidence supports the interpretation that teachers demonstrated changes in their planning practices during professional development, but it does not establish that the program alone caused these changes. Continued professional learning should therefore emphasize backward design, inquiry-oriented planning, and explicit alignment among intended graduate competencies, assessment strategies, and scientific learning experiences.

Learning Principles

Before the professional development, teachers were generally able to identify and explain the three principles of deep learning stipulated by the Ministry of Education (2025): mindful, meaningful, and joyful learning. Mindful learning was associated with conscious attention and awareness during learning; meaningful learning involved connections between learning and real-life contexts; and joyful learning involved positive and engaging learning experiences. Teachers reported that their initial understanding had been acquired through previous socialization activities.

This finding indicates that participants were not entirely unfamiliar with the individual principles of deep learning. Instead, their initial understanding appeared to be primarily conceptual and was not consistently accompanied by the ability to integrate the principles into an instructional planning framework. Accordingly, the preliminary finding that most teachers encountered deep learning for the first time is more appropriately interpreted as unfamiliarity with the integrated framework rather than complete unfamiliarity with every underlying principle. This interpretation requires confirmation against the wording of the preliminary interview questions.

Following the professional development, teachers reported that knowing the three principles conceptually did not automatically enable them to translate those principles into concrete learning designs. They described difficulties in moving from conventional practices emphasizing content coverage and memorization toward learning scenarios that emphasized depth of understanding. Teachers also expressed concern that emphasizing depth might reduce the amount of curriculum content they could cover. One teacher stated,

> *"When I relate the principles of learning to the design, I realize that it is easier to explain the theory than to design a mindful, meaningful and joyful activity. It is not as simple as I think because all learning steps must refer to the dimensions of the profile of graduates that have been determined".*

This statement highlights the distinction between declarative knowledge of pedagogical principles and the procedural knowledge required to operationalize them. The challenge was not simply to identify mindful, meaningful, and joyful learning but to coordinate these principles with graduate-profile dimensions, learning objectives, assessment strategies, and classroom activities. Such difficulties reinforce the importance of professional development that combines conceptual learning with practical planning, feedback, and reflection. Studies of science teacher professional development emphasize that changes in instructional practice may vary among participants and require sustained support (Gülhan, 2025).

Analysis of the learning-plan documents indicated that teachers at PAUD, primary, and secondary levels incorporated the three principles, although their forms of implementation varied. Mindful learning was represented through activities involving attention, awareness, reflection, breathing exercises, sensory experiences, and interaction with the surrounding environment. These activities were connected to LABIRIN's human–nature relationship and the exciting dimension through thinking and movement.

The document evidence suggests that teachers had begun to translate mindful learning from an abstract principle into identifiable instructional activities. Nevertheless, the presence of activities involving attention or awareness should not automatically be regarded as evidence

that students experienced mindful learning. Rather, the plans demonstrated teachers' intentions to promote awareness and purposeful engagement through structured learning experiences.

Meaningful learning was represented through activities connecting scientific concepts with students' everyday experiences, including melting ice to retrieve objects, constructing balloon-powered cars, investigating the effects of household waste on aquatic organisms, and developing digital campaigns related to cosmetic chemistry. These activities required students to explore, investigate, solve problems, reflect, and apply scientific concepts in contextual situations.

These examples indicate that meaningful learning became more visible when teachers connected scientific concepts to authentic situations and incorporated opportunities for investigation and application. Such instructional decisions are consistent with the emphasis on connecting knowledge and experience in meaningful learning (Sharan, 2015). They also demonstrate the potential relationship between LABIRIN's exciting and unique dimensions: intellectual and physical engagement can be combined with contextual problems and creative modes of expression. Research on contextual scientific understanding, including STEM-oriented approaches, further emphasizes the importance of connecting conceptual knowledge with meaningful applications (Novallyan et al., 2023).

Joyful learning was also incorporated into the learning designs. Teachers attempted to create activities that attracted attention and stimulated enthusiasm. However, the document and interview evidence revealed that some teachers still equated joyful learning primarily with students being happy, active, or entertained. One teacher stated,

> *"I think this joyful activity does not need to be associated with the learning objectives that have been set. The students are happy and laughing, and I think this is enough".*

This quotation reveals an important conceptual difficulty in translating joyful learning into purposeful instructional planning. Although positive emotions and enjoyable activities can contribute to student engagement, enjoyment alone does not demonstrate that intended learning outcomes are being addressed. The distinction is consistent with research emphasizing the behavioral, emotional, and cognitive dimensions of student engagement (Fredricks et al., 2004). Similarly, the ICAP framework highlights the importance of constructive and interactive cognitive engagement rather than equating observable activity with meaningful learning (Chi & Wylie, 2014).

Within LABIRIN, exciting learning should therefore be interpreted as purposeful engagement involving thinking, movement, and the construction of understanding rather than entertainment detached from instructional objectives. Likewise, the interactive and unique dimensions can support meaningful collaboration and contextual participation when their activities are aligned with intended learning outcomes. Research on creative and participatory science education provides a complementary perspective on designing activities that connect engagement with deeper learning opportunities (Kotsari & Smyrnaiou, 2021).

The findings also suggest that integrating the three principles requires attention to the coherence of the overall instructional design. A learning activity may simultaneously promote mindful attention, meaningful conceptual application, and joyful engagement, but these characteristics need to be supported by clear pedagogical purposes. The Indonesian literature on deep learning implementation similarly emphasizes the need to translate its principles into educational practices rather than treating them as isolated terminology (Nadawina et al., 2025).

Taken together, the interview, observation, and document evidence indicates that teachers demonstrated emerging competence in representing mindful, meaningful, and joyful learning within instructional plans. However, the quality of this integration remained variable, particularly when enjoyable activities were insufficiently connected to learning objectives. These findings support continued professional development emphasizing the alignment of

intended results, assessment evidence, and learning experiences (Wiggins & McTighe, 2005), while recognizing that conceptual familiarity alone does not establish mastery of instructional planning.

Learning Experience

Before the professional development, teachers were generally able to identify the three learning experiences within the deep-learning framework: understanding, applying, and reflecting. However, interview findings indicated that they sometimes interpreted "understanding" and "applying" through the categories of Revised Bloom's Taxonomy. Following the professional development, teachers reported a clearer distinction between the learning experiences in the deep-learning framework and the cognitive-process categories in Revised Bloom's Taxonomy. One teacher stated,

> *"When I hear the words understand and apply, they are always associated with Bloom's Taxonomy. It turns out that now I understand that the meaning of these words in the deep learning design is different".*

This quotation illustrates a developing understanding of the distinction between cognitive-process categories and the broader sequence of learning experiences emphasized in the Indonesian deep learning framework. Although the terms understanding and applying appear in both frameworks, their instructional functions are not necessarily identical. Revised Bloom's Taxonomy categorizes cognitive processes and knowledge dimensions, whereas the learning experiences of understanding, applying, and reflecting provide an orientation for organizing students' engagement with knowledge throughout the learning process (Anderson & Krathwohl, 2014). Recognizing this distinction can help teachers avoid treating learning experiences merely as labels attached to instructional activities.

Analysis of learning-plan documents showed that teachers incorporated learning experiences into their designs at PAUD, primary, and secondary levels. However, some learning steps were formulated as statements of learning objectives rather than as descriptions of what students would actually do.

This finding reveals an important difficulty in instructional planning. Learning objectives specify the knowledge, skills, or competencies students are expected to develop, whereas learning experiences describe how students engage in activities intended to support those outcomes. Confusing the two may produce lesson plans that identify intended achievements without sufficiently explaining the instructional processes through which students will work toward them. Consequently, teachers need to distinguish intended outcomes, assessment evidence, and learning activities. This distinction is consistent with backward-design principles (Wiggins & McTighe, 2005) and with research emphasizing explicit criteria for evaluating the quality of science teachers' lesson plans (Großmann & Krüger, 2024).

The difficulty also demonstrates why professional development should include opportunities to analyze examples of instructional plans and revise activities based on feedback. Teachers may recognize the terminology of a pedagogical framework but still need support in translating its components into student-centered learning sequences. Research on inquiry-based science teacher education identifies a similar challenge in connecting teachers' experiences of learning through inquiry with their capacity to design inquiry-oriented instruction (Strata et al., 2024).

Most activities identified in the learning plans were associated with LABIRIN's human–nature relationship, whereas activities explicitly representing the relationship between humans and God were less visible. The prominence of human–nature interactions is understandable within science education because scientific learning commonly involves the observation, investigation, and interpretation of natural phenomena. The relationship between humans and nature can therefore be represented directly through activities involving ecosystems, organisms, physical phenomena, and environmental issues.

In contrast, the relationship between humans and God requires careful pedagogical interpretation to ensure that its inclusion remains consistent with the learning objectives and the epistemological characteristics of science. Discussions concerning the integration and interconnection of science and religion provide relevant conceptual perspectives (Abdullah, 2020). However, the less frequent representation of this LABIRIN dimension should not automatically be interpreted as inadequate teacher understanding. Rather, it identifies an area requiring further clarification regarding how the dimension can be incorporated appropriately in science instructional planning.

The interview findings also indicated that teachers had rarely designed explicit reflection activities before the professional development, despite being familiar with reflection as one of the learning experiences in deep learning. Reflection is important because it can support students in examining their understanding, identifying difficulties, evaluating learning processes, and considering strategies for future learning. Following the professional development, teachers reported a clearer understanding of the relationship between reflection and intended learning outcomes. One teacher stated,

> *"I just realized that the entire learning experience in deep learning is related to the learning objectives that are elaborated from learning outcomes. So the experience of reflection must exist because reflection is in the learning goal".*

This statement suggests that teachers increasingly recognized reflection as an intentional learning experience rather than merely a routine closing activity. From an instructional planning perspective, reflection can provide opportunities for students to articulate their understanding, examine the evidence supporting their explanations, and identify areas requiring further learning. Reflection may also inform formative assessment when teachers use students' responses to identify learning difficulties and adjust subsequent instruction. Research synthesizing formative assessment practices in science education emphasizes the relevance of teachers' pedagogical understanding and collaborative professional learning in developing assessment practices (Atasoy & Kaya, 2022).

Learning-plan analysis further showed that reflection activities were generally included at the end of lessons and implemented orally or in written form. However, their depth varied. Some teachers developed reflection questions directly related to learning content, whereas others used general questions focused primarily on students' feelings or impressions.

This variation is important because the inclusion of reflection does not necessarily demonstrate that the activity promotes deeper conceptual understanding. Questions about students' feelings may provide information about emotional engagement, but questions addressing scientific explanations, evidence, difficulties, and learning strategies are more directly connected to cognitive reflection. Therefore, the quality of reflective learning should be interpreted in relation to its intended purpose and connection with learning objectives.

The distinction between reflection as a pedagogical intention and reflection as an observable learning process is also essential. The present study examined teachers' instructional plans and professional learning experiences rather than directly assessing the quality of students' reflection in classroom implementation. Consequently, the evidence supports claims about teachers' developing capacity to plan reflection activities, not conclusions about their effects on students' metacognitive development.

Taken together, the findings indicate that teachers demonstrated emerging development in conceptualizing and planning learning experiences. The most visible developments involved distinguishing deep learning experiences from Bloom's cognitive-process categories, recognizing reflection as an intentional component of instruction, and formulating more student-centered activities. However, difficulties remained in distinguishing objectives from activities, designing sufficiently specific reflection tasks, and integrating LABIRIN dimensions comprehensively. These findings indicate that professional learning should provide repeated

opportunities for instructional planning, feedback, reflection, and revision rather than assuming that conceptual understanding automatically produces coherent instructional designs.

Learning Framework

The learning framework in deep learning consists of four components: pedagogical practices, learning partnerships, learning environments, and digital technology (Ministry of Primary and Secondary Education, 2025). The findings indicate that teachers developed a more integrated understanding of these components during professional development, although their ability to translate this understanding into instructional plans remained variable. The analysis therefore considers each component in relation to teachers' prior knowledge, emerging planning practices, and continuing challenges.

Regarding pedagogical practices, teachers were familiar with project-based learning, problem-based learning, and inquiry learning before the training, but they did not always follow the specific syntax of each model. After the training, they recognized that learning models require systematic sequences of activities that should guide instructional planning. Analysis of the learning plans confirmed the use of project-based, problem-based, and inquiry learning, with inquiry emphasizing exploration, investigation, and problem-solving (Owolade et al., 2022).

This finding indicates that familiarity with instructional models does not necessarily ensure their appropriate application. Teachers need to understand the pedagogical purposes, activity sequences, and assessment implications of the models they select. Instructional models provide structured approaches to organizing teaching and learning processes, but their implementation requires adaptation to learning objectives and students' characteristics (Joyce et al., 2015; Sanjaya, 2016). In science education, inquiry-oriented models are particularly relevant because they can engage students in investigating phenomena, interpreting evidence, and constructing explanations. Ariani (2025) also addresses the design and expert validation of inquiry-based physics laboratory instruction, providing a relevant context for considering the systematic development of inquiry activities.

The teachers' difficulties are consistent with findings from a systematic review of inquiry-based science teacher education, which identified challenges in connecting teachers' experiences of inquiry with their capacity to teach through inquiry (Strata et al., 2024). Consequently, the present findings suggest that professional development should move beyond introducing model terminology toward examining instructional sequences and their alignment with intended science learning outcomes. These practices can support LABIRIN's interactive dimension by positioning teachers as facilitators and students as active participants in knowledge construction.

Regarding learning partnerships, teachers initially had limited experience involving external stakeholders. Following the training, they recognized parents, professionals, and community members as potential learning partners. The learning plans included contextual partnerships, such as inviting ride-hailing drivers to discuss fuel use and parents working as doctors to discuss personal hygiene.

These examples indicate that teachers were beginning to consider learning partnerships as resources for connecting scientific knowledge with authentic experiences. However, the pedagogical value of a partnership depends on how the partner's contribution is related to the intended learning objectives, scientific concepts, and students' characteristics. For example, a discussion with a ride-hailing driver may provide a contextual entry point for exploring fuel consumption, while a discussion with a medical professional may support learning about hygiene and health. Nevertheless, the presence of external participants in a lesson plan should not itself be interpreted as evidence of meaningful collaboration or improved learning.

The findings also point to the importance of institutional support in developing partnerships. Literature on educational supervision emphasizes the role of professional guidance and organizational support in strengthening instructional practices (Hartanto &

Purwanto, 2019; Hassanah et al., 2024). In the context of LABIRIN, meaningful partnerships may support the interactive dimension when they facilitate purposeful relationships among teachers, students, and community members. Further professional development should therefore help teachers identify suitable partners, clarify their instructional roles, and evaluate the relevance of their contributions.

Regarding learning environments, teachers had previously considered classroom conditions but did not always explicitly incorporate them into their learning plans. After the training, they recognized that learning environments should be adapted to the learning model and student activities. The learning plans included outdoor investigations, experiments, collaborative projects, and activities such as ecosystem investigations, natural-material water filtration, and greenhouse-effect experiments.

These examples demonstrate teachers' growing attention to learning environments as integral components of instructional planning rather than merely physical settings. Outdoor investigations and experimental activities provide opportunities for students to encounter scientific phenomena directly, engage in collaborative inquiry, and connect observations with scientific explanations. This interpretation is consistent with Haq and Prasetiyo (2025) and Paleenud et al. (2024), who discuss the relevance of learning environments and instructional approaches to deeper learning.

The integration of the learning environment with LABIRIN is particularly evident in the interactive dimension, including relationships among students and between humans and nature. However, the quality of this integration depends on whether the selected environment enables students to engage meaningfully with intended learning outcomes. Schools with limited facilities may require alternative approaches, such as locally available materials, outdoor observations, and small-scale investigations. Thus, professional development should support teachers in selecting learning environments that are safe, accessible, contextually appropriate, and pedagogically purposeful.

Regarding digital technology, teachers had already used digital tools before the training but tended to associate them with making learning more modern or engaging. After the training, they recognized that technology should be selected based on learning objectives and indicators rather than used merely as an additional tool. Learning-plan analysis revealed both less purposeful use, such as technology for ice-breaking, and more meaningful applications, including VR for exploring the solar system and AR through Assemblr for visualizing body organs.

These findings illustrate the distinction between using technology to attract students' attention and selecting digital resources to support conceptual understanding. Visualization technologies may provide opportunities to explore scientific phenomena that are difficult to observe directly, but their educational value depends on the questions, activities, and learning objectives associated with their use. Research on technology-supported learning highlights the importance of considering how technological developments shape learning environments (Dewi, 2022; Norova et al., 2025). Similarly, Syaadah et al. (2025) describe the development of an interactive learning website using a deep learning approach in thermodynamics, providing a relevant example of the connection between digital resources and science instructional design.

The findings also suggest that teachers need to evaluate the pedagogical relevance of digital technologies rather than assuming that technological sophistication automatically leads to deeper learning. The potential of digital resources should be considered alongside accessibility, students' learning needs, and opportunities for meaningful teacher–student interaction. This concern is consistent with discussions of digital transformation and educational technology use (Rohayati & Abdillah, 2024; Welsen et al., 2023). Within LABIRIN, digital technology may support the unique dimension by enabling creative visualizations and contextually adapted learning experiences. However, technology should

remain a means of achieving instructional objectives rather than an objective in itself.

Across the four components, the findings indicate that teachers increasingly recognized the importance of integrating pedagogical practices, partnerships, learning environments, and digital resources into coherent instructional designs. Nevertheless, their developing competence was not uniform. Some teachers demonstrated greater attention to the alignment between instructional decisions and intended outcomes, while others continued to experience difficulties in selecting appropriate models, planning partnerships, or using technology purposefully. This variation is consistent with research showing that science teachers may respond differently to professional development because changes in instructional practice involve complex processes of interpretation, reflection, and adaptation (Tsaliki et al., 2024).

Overall, the present study suggests that LABIRIN offers a potentially useful orientation for examining the integration of deep learning components in science instructional planning. The findings do not establish the effectiveness of LABIRIN in classroom implementation or student learning outcomes. Rather, they demonstrate emerging developments and persistent challenges in teachers' planning practices. Continued professional development should therefore provide opportunities for collaborative instructional design, feedback, and revision, with explicit attention to the alignment among learning objectives, pedagogical practices, learning partnerships, learning environments, and digital technologies.

CONCLUSION

This study shows that professional development strengthened science teachers' ability to plan deep learning based on LABIRIN. The training helped teachers move from a general conceptual understanding of deep learning toward a more structured ability to translate its components into learning plans. Teachers developed a clearer understanding of the four deep learning components graduate profile, learning principles, learning experiences, and learning framework and their connections with the LABIRIN dimensions of exciting, interactive, and unique learning.

The findings indicate that teachers were able to integrate deep learning and LABIRIN through contextual learning experiences, student-centered activities, scientific investigation, reflection, interaction, collaboration, creative expression, and purposeful use of technology. However, several challenges remained. Teachers still needed support in distinguishing learning objectives from learning activities, aligning learning experiences and reflection with intended outcomes, ensuring that joyful activities contribute to learning objectives, applying appropriate learning-model syntax, developing meaningful learning partnerships, and using digital technology purposefully. Therefore, professional development based on LABIRIN should be continued through practical guidance on backward design, inquiry learning, student-centered instructional strategies, reflective learning, partnership development, and purposeful technology integration. Overall, LABIRIN provides a flexible framework for supporting teachers in translating the principles of deep learning into contextual, engaging, interactive, and meaningful science learning designs.

RECOMMENDATION

Future research should examine the implementation and effectiveness of LABIRIN-based deep learning designs developed through teacher professional development. Further studies are recommended to investigate how these designs are implemented in actual science classrooms and how they influence students' learning outcomes, critical thinking, creativity, engagement, and other graduate-profile dimensions. Longitudinal studies could also be conducted to examine the sustainability of changes in teachers' instructional practices after professional development.

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AUTHOR CONTRIBUTIONS STATEMENT

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Rinda Angghita Putri	✓	✓			✓	✓		✓	✓	✓		✓		
Anggie Siti Perdani		✓		✓	✓	✓		✓		✓			✓	
Dhita Rismayani	✓				✓		✓	✓	✓	✓	✓			✓

CONFLICT OF INTEREST STATEMENT
Authors state no conflict of interest.

ETHICAL APPROVAL
This study was conducted in accordance with applicable institutional policies and ethical principles for educational research. Participation in the teacher professional development activities was voluntary, and all participants were informed about the purpose of the study. Appropriate measures were taken to maintain the confidentiality of participants' information and to ensure that the data collected were used solely for research purposes.

DATA AVAILABILITY
The data supporting the findings of this study are available from the corresponding author upon reasonable request.

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