



Investigating Teachers' Conceptualizations of Deep Learning in Science Education

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Abstract

This study investigates junior high school science teachers' conceptualizations of deep learning within the context of Indonesian educational reform. Using a qualitative descriptive approach, data were collected from 39 science teachers in Cirebon through open-ended questionnaires and analyzed thematically using Atlas.ti. The results reveal that teachers define deep learning as a holistic process that integrates cognitive, affective, and psychomotor dimensions, emphasizing student-centeredness, collaboration, and meaningful learning. Teachers further articulated key principles of deep learning, including contextualization, critical and creative reasoning, innovation, independence, joyful and mindful learning, ethical awareness, and the ability to connect science concepts to real-life situations. The implementation of deep learning was characterized by project-based learning, authentic tasks, collaborative practices, backward design, and supportive classroom environments. However, teachers reported challenges such as limited resources, unequal technological access, time constraints, and diverse student readiness, indicating the complexity of translating deep learning into practice. To address these issues, teachers highlighted the need for systematic supports including sustained professional training, mentoring, peer observation, and high-quality instructional modules. The study contributes theoretically by clarifying teacher perspectives on deep learning and practically by offering recommendations for professional development and policy directions to strengthen deep learning in Indonesian science education.

Keywords:

Deep learning; science education; teacher conceptualization; professional development

History

Received:
September
29, 2025

Revised:
February 8,
2026

Accepted:
Februari 16,
2026

How to cite:

Fatnah, N., Zakiyyah, Z., & Cahyani, M. D. (2026). Investigating Teachers' Conceptualizations of Deep Learning in Science Education. *Journal of Science Education Research*, 10(1), 49-60. doi: <https://doi.org/10.21831/jserv10i1.255040>.

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1. INTRODUCTION

The discourse on 21st-century education has increasingly emphasized the necessity of preparing students not only with subject-matter knowledge but also with higher-order skills such as critical thinking, creativity, problem-solving, and the ability to apply concepts to authentic contexts. Deep learning as a pedagogical paradigm responds to this challenge by promoting conceptual integration, sustained inquiry, and reflective practice (Chunmeng Weng, 2022). In science education, deep learning offers opportunities for students to connect theoretical concepts with real-world issues, thereby fostering both scientific literacy and meaningful learning (Krajcik, 2019). These global trends resonate strongly with recent reforms in Indonesia, including the Merdeka Curriculum and the Profil Pelajar Pancasila framework, which highlight deeper, competency-oriented learning outcomes. Project-Based Learning (PjBL) has often been regarded as a vehicle for operationalizing deep learning since it situates learners in collaborative and inquiry-driven projects that demand reflection and sustained reasoning. Empirical studies in Indonesia demonstrate that PjBL integrated with local wisdom not only strengthens conceptual understanding but also enhances students' sense of cultural identity. For example, (Fatimatuz Zahroh, 2022) showed that PjBL based on local Plantae materials significantly improved students'

scientific literacy (N-Gain = 0.66). Similarly, (Sary, Isnawati, & Asri, 2023) validated modules integrating fungi-based local wisdom within PjBL, confirming strong media and material validity. Beyond these, PjBL embedded with cultural practices effectively enhanced 21st-century skills, while bibliometric studies also confirm the growing trend of integrating local wisdom into science pedagogy (Zaki, 2024). Recent studies within the Indonesian research landscape have further contributed by highlighting science learning innovations, including the use of AI in science education (Harianti, Kadarohman, & Anwar, 2025) and Augmented Reality-based learning media (Maryanto, Rosana, & Setyawarno, 2020), underscoring the national urgency for transformative pedagogical approaches.

Despite these advances, existing studies have predominantly examined student outcomes or focused on the development and validation of teaching modules. Few have investigated how teachers themselves conceptualize deep learning, even though teacher cognition is crucial in shaping classroom practices. Research in other contexts has shown that when teachers' conceptual clarity about deep learning is limited, instructional practices tend to regress into surface-level tasks rather than fostering genuine conceptual depth (Sølvik & Glenna, 2022) (Darling-Hammond, 2023). Recent Indonesian findings echo this concern, revealing that many teachers conflate deep learning with general "active learning" or "student-centered approaches" (Permatasari, Rokhmaniyah, & Hidayah, 2025). Such partial understandings may create a misalignment between policy aspirations and classroom realities. The current study therefore seeks to address this critical research gap by investigating junior high school science teachers' conceptualizations of deep learning. Specifically, it aims to explore how teachers define deep learning, identify the principles they emphasize, describe their reported practices, and articulate challenges and support needs in implementation. The findings are expected to contribute to the literature by clarifying the current state of teacher understanding in Indonesia, informing the design of professional development programs, and offering recommendations for policies that support authentic deep learning in science classrooms. This contribution aligns with both international calls for evidence-based teacher development (Wojcikiewicz, 2024) and national priorities articulated in Indonesian science education reform.

In light of this background, the research problem of this study centers on the tension between the extensive promotion of deep learning in educational policy and curriculum and the limited empirical evidence about how science teachers themselves conceptualize this paradigm. Although deep learning has become a central discourse in Indonesian education reform, little is known about how teachers interpret its meaning and how their conceptualizations shape classroom practice. To address this gap, the present study aims to analyze how junior high school science teachers conceptualize deep learning, the principles they associate with it, the ways they report implementing it in their classrooms, as well as the challenges and forms of support they identify as necessary for its effective enactment. Through this focus, the study seeks to contribute theoretically by clarifying teachers' understanding and practical contributions of deep learning by informing the design of professional development programs and policy directions that support the advancement of authentic deep learning in Indonesian science education.

2. LITERATURE REVIEW

2.1. Deep Learning in Science Education

Deep learning in science education refers to a learning process in which students develop meaningful conceptual understanding by actively connecting scientific ideas with inquiry processes, real-world contexts, and reflective thinking. Unlike surface learning, which primarily focuses on rote memorization of isolated facts, deep learning encourages students to analyze relationships among concepts, interpret evidence, and apply knowledge to authentic problems. Research indicates that learning environments designed to support deeper learning can significantly improve student engagement, conceptual understanding, and scientific literacy (Buder & Hesse, 2023; Putri et al., 2025). Through inquiry-oriented activities and interactive learning environments, students integrate theoretical knowledge with empirical investigation. This integration promotes meaningful learning and supports the development of higher-order thinking skills required for contemporary science education (Santana et al., 2020; Chamola et al., 2026).

In science classrooms, deep learning is also characterized by students' active involvement in constructing explanations, evaluating evidence, and reflecting on their understanding of scientific phenomena. Learners who adopt a deep approach tend to demonstrate intrinsic motivation, use meaningful learning strategies, and seek conceptual coherence rather than relying on rote memorization. Such learning processes are supported by constructivist learning environments that encourage exploration, collaboration, and sustained inquiry. Within this perspective, instructional approaches that provide opportunities for students to investigate authentic problems and produce meaningful learning artifacts are considered particularly conducive to deep learning. One example is Project-Based Learning (PjBL), which has been shown to promote deep learning strategies and motivation among learners (Jiang, 2008). Therefore, understanding how pedagogical approaches such as PjBL

support deep learning is therefore essential for examining effective practices in science education. However, while PjBL has been widely recognized as an approach that supports deep learning, limited research has examined how teachers themselves understand and enact deep learning within science classrooms.

2.2. Project-Based Learning as a Pedagogical Approach for Deep Learning

Project-Based Learning (PjBL) is widely recognized as a pedagogical approach that promotes deep learning by engaging students in authentic projects that require sustained inquiry and active participation. Rooted in constructivist learning theory, PjBL emphasizes student-centered learning in which learners explore real-world problems, develop solutions, and construct knowledge through inquiry and collaboration. Rather than focusing solely on the transmission of information, PjBL encourages students to analyze complex issues, integrate knowledge from multiple sources, and apply scientific concepts to practical contexts. Such processes foster higher-order thinking skills, including critical thinking, creativity, and problem-solving, which are essential competencies in contemporary education. Research has shown that project-based learning can enhance students' conceptual understanding, engagement, and ability to connect theoretical knowledge with real-world applications (Eswaran, 2024; Zhang et al., 2023; Ramaila, 2025). Through sustained inquiry and collaborative work, students are encouraged to take ownership of their learning, thereby strengthening their motivation and developing deeper approaches to understanding academic content.

In addition to promoting cognitive engagement, PjBL also creates learning environments that support collaboration, communication, and reflective learning. By working in teams to investigate authentic problems, students develop interpersonal skills and co-construct knowledge, which further reinforces meaningful learning experiences (Mutanga, 2024). Empirical studies have also demonstrated that structured project activities can significantly improve students' problem-solving abilities and critical thinking skills, while simultaneously increasing their motivation and engagement in learning processes (Bhosale, 2020; Bhagwat & Kulkarni, 2025). Effective implementation of PjBL often involves carefully designed project stages, iterative feedback, and opportunities for reflection, enabling students to progressively refine their understanding throughout the learning process (Ntunka et al., 2024). As such, PjBL provides a powerful instructional framework for fostering deep learning in educational settings. However, the success of this approach largely depends on how teachers interpret, design, and implement deep learning principles in their instructional practices. This highlights the importance of examining teachers' conceptualizations and enactment of deep learning in classroom contexts.

2.3. Teacher Conceptualization and Implementation of Deep Learning

Teachers' conceptualizations of deep learning play a crucial role in shaping instructional design and classroom enactment. In educational contexts, deep learning is commonly understood as a learning approach that emphasizes meaningful understanding, critical thinking, and the integration of new knowledge with prior knowledge structures. Studies indicate that teachers often associate deep learning with interdisciplinary learning, formative assessment practices, and opportunities for students to actively construct knowledge through inquiry and reflection (Burner & Schipor, 2025; Yang & Yu, 2019). When teachers possess a clear conceptual understanding of deep learning principles, they are more likely to design learning environments that encourage analysis, problem-solving, and knowledge transfer across contexts. Professional development and collaborative learning communities also play an important role in strengthening teachers' understanding of deep learning, enabling them to reflect on instructional strategies and share pedagogical insights with colleagues (Korsager et al., 2023). Such professional engagement can shift teachers' perspectives toward more learner-centered approaches and increase their confidence in implementing deep learning practices.

Despite its recognized benefits, implementing deep learning in classroom practice remains challenging in many educational settings. Teachers often face barriers such as limited technological infrastructure, disparities in digital literacy, and insufficient institutional support, which can hinder the effective adoption of deep learning-oriented pedagogies (Pahrudin et al., 2025). Empirical studies further indicate that the extent to which teachers implement deep learning practices varies depending on teaching experience, subject area, and access to professional development opportunities (Al-Dawood, 2025; Putri et al., 2025). In some cases, teachers incorporate deep learning strategies through problem-based instruction, collaborative learning activities, and formative assessment practices that promote higher-order thinking skills (Tian et al., 2022). However, meaningful implementation requires not only pedagogical knowledge but also institutional support, adequate resources, and ongoing professional learning opportunities. Therefore, investigating how teachers conceptualize deep learning and how these conceptualizations influence their instructional practices is essential for understanding the implementation of deep learning in science education.

3. RESEARCH METHOD

3.1 Type of Research

This research employed a qualitative descriptive approach to explore science teachers' conceptualizations of deep learning. The choice of a qualitative descriptive design was based on the need to capture teachers' perspectives in their own words, focusing on how they define, interpret, and describe their classroom practices related to deep learning. According to (Sandelowski, 2000) qualitative descriptive research is appropriate for studies that seek to provide straightforward descriptions of phenomena as experienced by participants, without imposing heavy theoretical interpretation. This approach aligns with the exploratory nature of the present study, which sought to document the range of teachers' understandings of deep learning in science education.

3.2 Time and Place of Study

The study was conducted in August 2025 in Cirebon, West Java, Indonesia. Data were collected from science teachers working in junior high schools in Cirebon Regency, particularly in the Sumber area. The location was selected purposively due to its accessibility and the active involvement of local teachers in professional development initiatives. As (Yin, 2017) points out, specifying the context of qualitative research is essential for ensuring the transparency and transferability of findings.

3.3 Research Subject and Procedures

The participants of this study were 39 junior high school science teachers who voluntarily participated by completing an open-ended questionnaire distributed via Google Forms. Teachers were invited through professional teacher networks and school contacts, and participation was entirely voluntary with informed consent obtained at the outset. The procedure consisted of several stages: (1) development of the open-ended questionnaire, (2) distribution of the questionnaire link through online platforms, (3) collection of responses within a two-week period, and (4) organization of the responses for analysis.

The open-ended questionnaire was structured to capture teachers' perspectives across five dimensions: (1) their definition of deep learning, (2) the principles of deep learning they recognize, (3) how they implement deep learning in classroom practices, (4) the challenges they face in applying it, and (5) the forms of support they perceive as necessary. Designing items around these five dimensions allowed for the systematic collection of narrative data that reflect both conceptual and practical aspects of deep learning in science classrooms. As (Morse, 2015) note, purposive strategies and targeted questions help capture the diversity of perspectives needed to illuminate complex educational phenomena.

3.4 Data collection and analysis techniques

Data collection relied exclusively on participants' written responses to the open-ended questionnaire items. All responses were exported from Google Forms into Microsoft Excel and subsequently prepared for analysis. Thematic content analysis was applied, following the guidelines of (Braun, 2019), which involve familiarization with the data, generating initial codes, identifying categories, and developing overarching themes. Coding was facilitated using Atlas.ti software, which supported the systematic organization of data and the visualization of connections among codes.

To ensure the trustworthiness of the findings, several strategies were employed: (a) peer debriefing with colleagues to validate coding decisions, (b) inclusion of illustrative quotes from teachers to enhance credibility, and (c) maintaining an audit trail of analytical decisions. Ethical considerations were also prioritized by ensuring voluntary participation, obtaining informed consent, protecting participants' anonymity, and securing the data in accordance with the BERA ethical guidelines for educational research (Ethical Guidelines for Educational Research, 2018).

4. RESULT AND DISCUSSION

The analysis of teachers' responses reveals a complex understanding of deep learning that integrates conceptual, pedagogical, and contextual dimensions. The coding network generated through ATLAS.ti, presented in Figure 1, illustrates how teachers conceptualize deep learning around the central theme of in-depth learning. This theme is interconnected with several related dimensions that collectively describe meaningful engagement in science learning. Teachers frequently described deep learning as a holistic process integrating cognitive, affective, and experiential dimensions. These dimensions represent cognitive engagement, emotional involvement, and experiential participation, indicating that teachers perceive deep learning as a process in which knowledge construction occurs through the integration of intellectual, affective, and practical experiences.

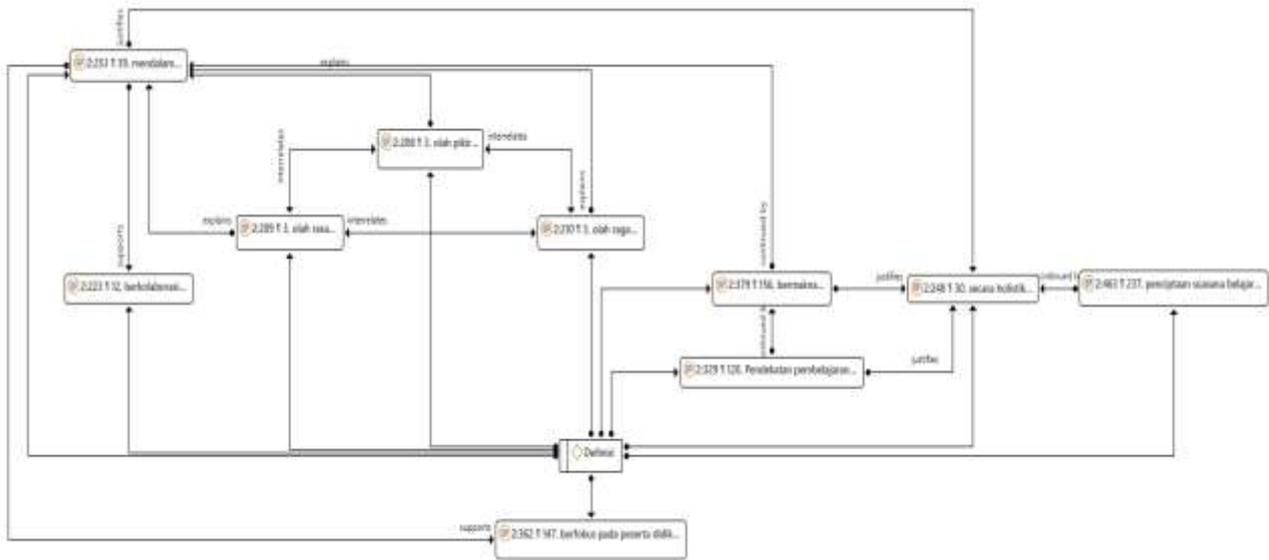


Figure 1. Atlas.ti network of teachers' conceptualizations of deep learning (Definition dimension)

Such interpretations are consistent with global perspectives that frame deep learning as conceptual understanding, knowledge integration, and meaningful application of ideas (Kovač, 2023) (Darling-Hammond, 2023). However, the findings of this study reveal an additional cultural dimension in teachers' interpretations of deep learning. Teachers conceptualize deep learning as a holistic educational process that integrates cognitive, affective, and experiential dimensions of learning. This perspective reflects a broader educational philosophy in which learning is understood not only as a cognitive activity but also as a process of balanced human development that connects intellectual inquiry with emotional engagement and experiential growth. Similar tensions between theoretical definitions of deep learning and its classroom enactment have been identified in previous research (Sølvik & Glenna, 2022) (Permatasari, Rokhmaniyah, & Hidayah, 2025), indicating that teachers often interpret deep learning through locally grounded pedagogical perspectives.

The coding analysis reveals that teachers associate deep learning with a set of pedagogical principles that guide classroom practices. As illustrated in Figure 2, these principles include contextualization, meaningful learning, critical and creative reasoning, innovation, learner independence, joyful and mindful learning, ethical awareness, and the ability to connect learning with real-life situations. Teachers consistently emphasized contextualization as a fundamental element of deep learning, noting that scientific concepts become meaningful when students relate them to their everyday experiences. This finding aligns with previous studies demonstrating that contextual and collaborative pedagogies foster deeper cognitive engagement and conceptual understanding (Setyowati, Rahayu, & Listiaji, 2025).

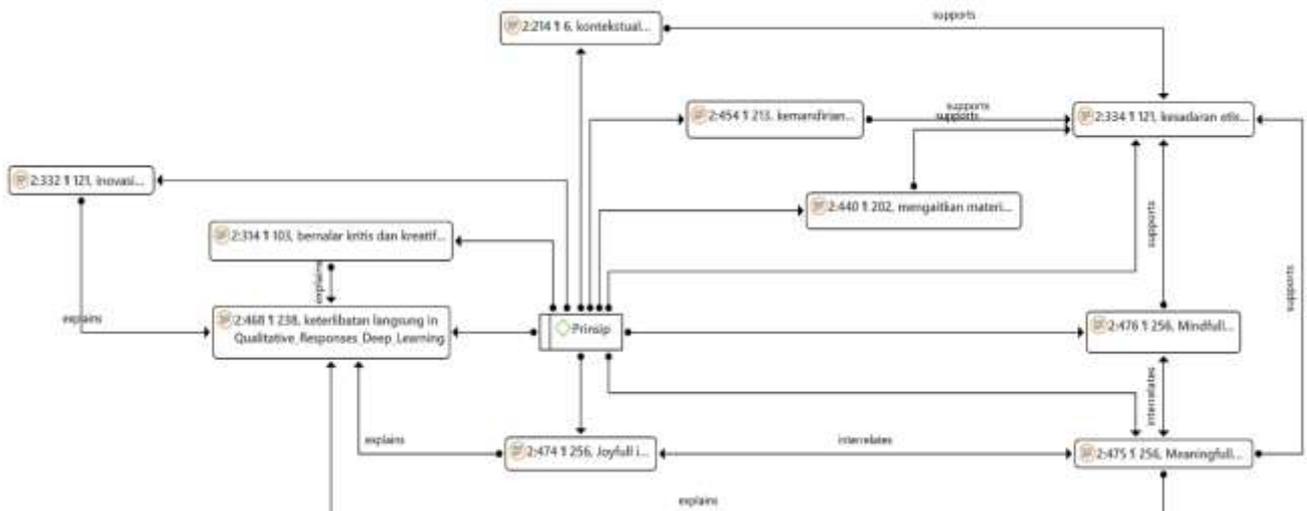


Figure 2. Atlas.ti network of teachers' conceptualizations of the principles of deep learning (Prinsip dimension)

In addition to contextualization, teachers frequently highlighted the role of critical and creative reasoning. Respondents described learning processes in which students analyze complex problems, explore alternative

explanations, and design innovative solutions. Such perspectives are consistent with research suggesting that simulation-based and inquiry-oriented pedagogies promote higher-order thinking and innovation in science education (Levin, 2024). Similarly, studies on deep learning emphasize that creativity and innovation represent core competencies developed through inquiry-driven learning environments (Weng, Chen, & Ai, 2023). Another important principle emerging from the data is learner independence. Teachers emphasized that deep learning requires students to take responsibility for their learning rather than relying solely on teacher explanations. This interpretation resonates with studies highlighting the importance of learner autonomy in sustaining inquiry and knowledge construction (Vashishth, Sharma, Sharma, Sharma, & Sharma, 2025). In addition, teachers emphasized emotional and ethical dimensions as integral components of deep learning. Joyful and mindful learning environments were perceived as essential for sustaining curiosity and engagement during inquiry activities. Previous studies demonstrate that emotional engagement significantly enhances learning motivation and academic performance (Liu, Ma, & Chen, 2024). Furthermore, the inclusion of ethical awareness reflects the idea that deep learning should guide students toward responsible decision-making in scientific and technological contexts (Alhebaishi, Stone, & Ameen, 2025) (Giannakos, 2025).

Teachers' descriptions of classroom practices further illustrate how these principles translate into instructional strategies. The coding network presented in Figure 3 indicates that teachers commonly implement deep learning through project-based learning, authentic inquiry activities, collaborative discussions, and outcome-oriented instructional planning. Project-based learning was frequently identified as a central approach because it enables students to engage in sustained investigation and collaborative problem-solving. Empirical studies have shown that project-based learning can significantly improve students' conceptual understanding and higher-order thinking skills (Zhang & Ma, 2023).

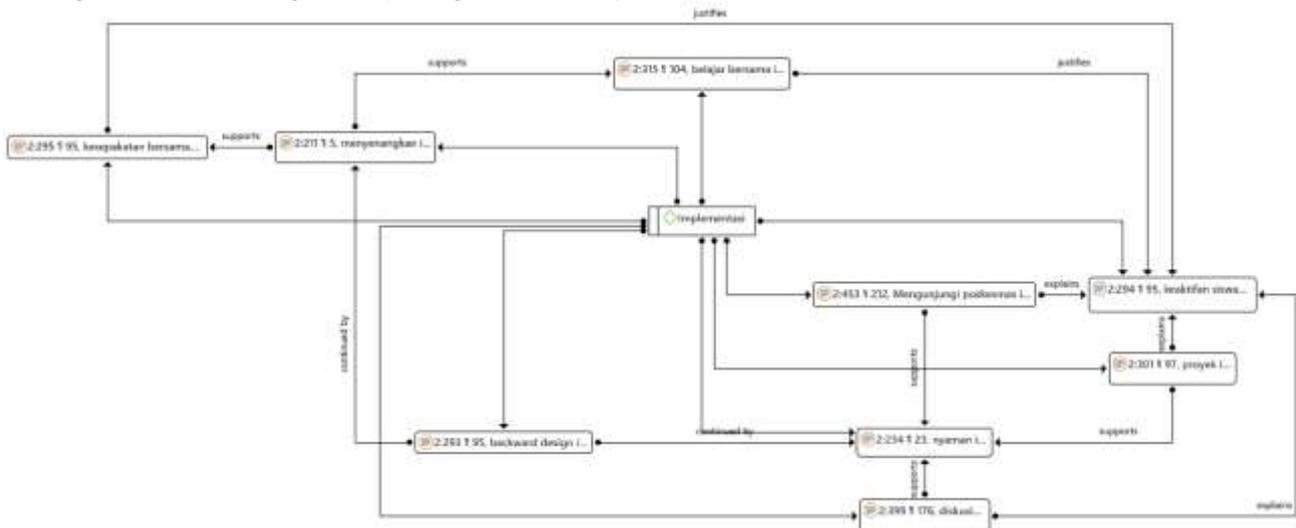


Figure 3. Atlas.ti network of teachers' conceptualizations of deep learning implementation (Implementasi dimension)

Teachers also reported incorporating authentic learning experiences, such as contextual investigations and community-based observations, enabling students to connect theoretical knowledge with real-world phenomena. Research suggests that authentic learning environments effectively bridge the gap between conceptual knowledge and practical application (Garcia MB, 2023). Another important strategy involves backward design, in which teachers begin lesson planning by identifying desired learning outcomes before designing instructional activities. This approach aligns with the Understanding by Design framework, which emphasizes outcome-oriented curriculum planning (Newell, 2023). Furthermore, teachers emphasized the importance of supportive classroom environments that encourage open discussion and collaborative learning. Positive educational environments have been shown to significantly improve student engagement and academic performance (Kassab, 2024). The emphasis on collaboration also reflects broader research demonstrating that cooperative learning practices strengthen critical discourse and knowledge construction among students (Yang, 2023).

Despite these pedagogical efforts, teachers reported several challenges in effectively implementing deep learning. As illustrated in Figure 4, these challenges involve structural, pedagogical, and learner-related factors. Structural challenges include limited infrastructure, unequal access to technology, and time constraints within the school schedule. Inquiry-based learning activities often require extended time for investigation and reflection, which can be difficult to accommodate within traditional classroom schedules. Similar structural

barriers have been reported in previous studies examining innovative teaching practices (Huang, 2020) (Beege, 2023).

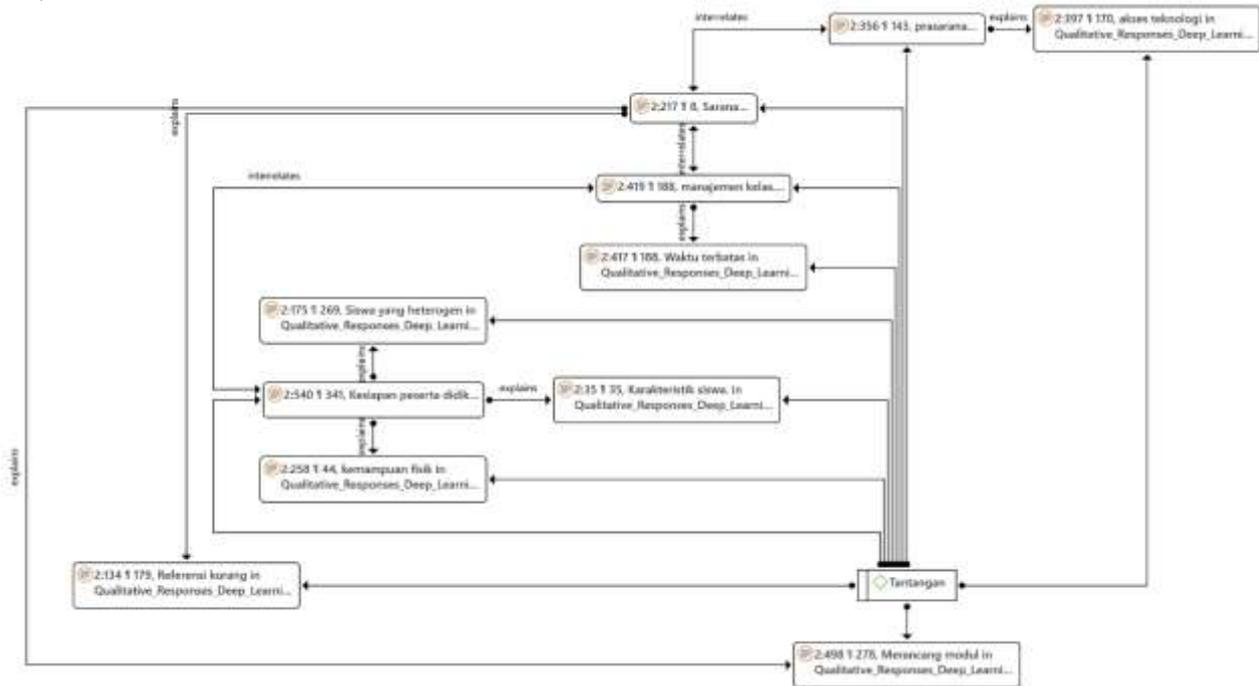


Figure 4. Atlas.ti network of teachers' perspectives on challenges (Tantangan) in implementing deep learning

Pedagogical challenges were also frequently mentioned. Teachers indicated that designing learning modules aligned with deep learning principles requires substantial preparation and access to appropriate instructional resources. Many respondents reported limited instructional references that demonstrate how deep learning principles can be implemented in classroom practice. Previous research similarly highlights the difficulty teachers face when attempting to transform pedagogical frameworks into concrete instructional designs (du Preez, 2025). In addition, teachers highlighted the diversity of student readiness, learning characteristics, and physical abilities, which requires differentiated instructional strategies and additional scaffolding. Such challenges are consistent with studies emphasizing that student diversity represents a significant consideration when implementing innovative pedagogies (Nguyen, 2024) (Kassab, 2024).

Teachers also emphasized the importance of systematic support for implementing deep learning. The word cloud presented in Figure 5 illustrates several forms of support identified by teachers, including professional training, mentoring, instructional modules, peer observation, and practical teaching guidelines. Professional development emerged as the most frequently mentioned form of support. Teachers emphasized that sustained training programs are necessary to deepen their understanding of deep learning and to develop practical strategies for classroom practice. Previous studies indicate that effective professional development programs should involve sustained collaboration, mentoring, and opportunities for reflective practice (Khalil & Gunduz, 2023).



Figure 5. Word cloud of teachers' perspectives on supports (Dukungan) for implementing deep learning.

Mentoring and peer collaboration were also identified as important mechanisms for professional learning. Teachers suggested that observing colleagues' teaching practices and engaging in collaborative reflection could help them refine their instructional approaches. Research on teacher professional development similarly shows that mentoring programs and peer coaching can significantly enhance teachers' pedagogical competencies (Sivertsen Arnsby, 2023) (Leijen, 2022). In addition, teachers emphasized the need for accessible instructional

modules and practical teaching guides. Previous studies report that many teachers experience difficulties implementing innovative pedagogies due to limited access to appropriate instructional materials (Aisyah & Novita, 2025). The findings of this study therefore reinforce the importance of comprehensive professional support systems that combine training, mentoring, collaborative learning, and high-quality instructional resources (Fry, 2025).

To synthesize these findings, Table 1. summarizes the main dimensions of teachers’ conceptualizations of deep learning, including their definitions, pedagogical principles, implementation practices, challenges, and support needs.

Table 1. Synthesis of Teachers’ Conceptualizations of Deep Learning.

Dimension	Key Themes	Interpretation
Definition	Integration of thinking, feeling, and action	Deep learning involves cognitive, emotional, and experiential engagement
Principles	Contextualization, reasoning, innovation, independence	Deep learning develops higher-order thinking and meaningful engagement
Implementation	Project-based learning, authentic learning, collaboration	Instruction integrates inquiry activities and real-world contexts
Challenges	Infrastructure, time constraints, learner diversity	Implementation depends on structural and pedagogical conditions
Support	Training, mentoring, teaching resources	Professional development and institutional support are essential

The relationships among these findings are illustrated in the conceptual model presented in Figure 6. The model demonstrates that teachers’ conceptualizations of deep learning constitute the foundation for instructional practices. These conceptualizations consist of two interrelated components: the definition of deep learning and the pedagogical principles that guide classroom practice. Together, these dimensions shape the implementation of instructional strategies such as project-based learning, authentic inquiry activities, collaborative learning, and outcome-oriented instructional planning.

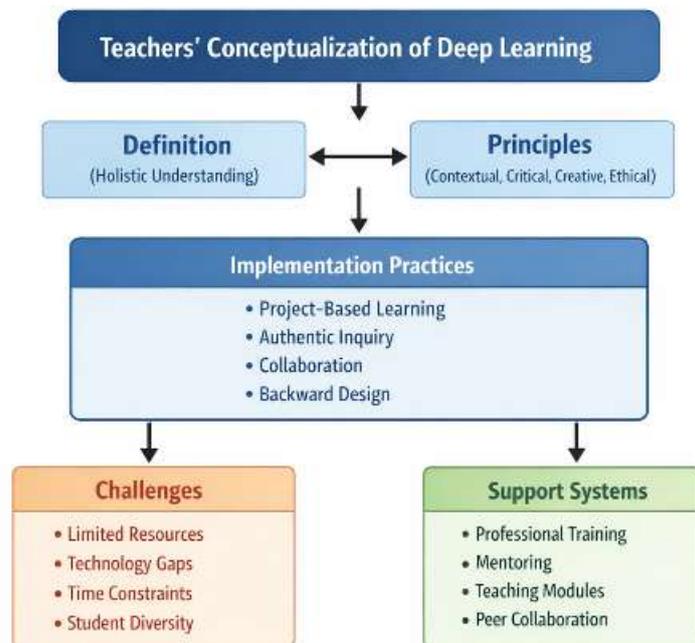


Figure 6. Conceptual Model of Teachers’ Conceptualizations of Deep Learning

However, the implementation of deep learning is influenced by several contextual factors. Structural challenges such as limited resources, technological inequality, and time constraints may hinder implementation. At the same time, institutional support systems, including professional training, mentoring, peer collaboration, and access to instructional resources, can facilitate the enactment of pedagogical principles in classroom

practice. This conceptual model highlights that the successful implementation of deep learning depends not only on teachers' conceptual understanding but also on systemic support within educational institutions.

5. CONCLUSION

This study concludes that junior high school science teachers conceptualize deep learning as a multidimensional construct integrating cognitive, affective, and experiential domains. While their perspectives align with international frameworks emphasizing contextualization, critical and creative reasoning, innovation, independence, and joyful learning, teachers continue to face challenges related to limited resources, technological inequality, time constraints, and diverse student readiness. These findings highlight the need for sustained professional development, mentoring, peer collaboration, and access to high-quality teaching modules to support the effective implementation of deep learning. Such efforts are essential for aligning classroom practice with Indonesian educational reforms and global calls for transformative pedagogy.

ACKNOWLEDGMENTS

This research was made possible through the 2025 BIMA grant from the Ministry of Higher Education, Science, and Technology of Indonesia (Kemendikristek). The authors would like to sincerely thank the junior high school science teachers who collaborated and contributed their valuable time and insights to this study. Their participation and commitment greatly enriched the findings and ensured the relevance of this work to classroom practice.

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