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Implementation of Deep Learning and the Development of Conceptual Understanding among Elementary School Students at SD Negeri 13 Kubu

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ABSTRACT

Deep learning in elementary education is often discussed in terms of student engagement and learning outcomes, while less is known about the pedagogical processes through which it supports conceptual understanding. This study examines how deep learning is implemented in elementary IPAS learning, identifies the processes through which students construct and refine conceptual understanding, and develops an empirically grounded conceptual model. A qualitative single-case study was conducted in a Grade 5 classroom at an elementary school in Kubu Raya, Indonesia. Data were collected through classroom observations, semi-structured interviews, and document analysis involving one teacher, 17 students, and one school principal. Data were analyzed through data condensation, data display, cross-source comparison, and conclusion drawing and verification. The analysis identified five interconnected pedagogical mechanisms: activation of prior knowledge, collaborative meaning-making, scaffolding and formative feedback, reflection on understanding, and contextual application. Mindful learning supported attention and cognitive readiness, meaningful learning functioned as the primary process of conceptual construction and refinement, while joyful learning provided conditions for sustained participation. These dimensions operated recursively rather than sequentially, through which students constructed, examined, revised, and applied emerging understanding. The study proposes a Systemic Deep Learning Model for Conceptual Understanding Formation, offering a process-oriented explanation of how deep learning may support conceptual development in elementary IPAS learning.

Keywords: Deep learning; Conceptual Understanding; Elementary Education; Ipas Learning; Pedagogical Mechanisms

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INTRODUCTION

The demands of twenty-first-century education have shifted the focus of learning from knowledge transmission toward approaches that position students as active participants in constructing, examining, and applying knowledge. In increasingly complex and interconnected societies, students are expected not only to acquire information but also to develop critical thinking, creativity, collaboration, communication, and the ability to use knowledge flexibly across contexts (UNESCO, 2021). These demands highlight the importance of conceptual understanding, which enables learners to organize knowledge, recognize relationships among ideas, explain underlying principles, and use concepts to interpret and respond to problems beyond routine classroom tasks. Conceptual understanding is therefore not simply the accumulation of factual knowledge but involves the ability to construct meaning, connect ideas, reason about relationships, and use knowledge purposefully.

Conceptual understanding is particularly important in elementary science-related learning because students are expected to connect observations with scientific concepts, explain relationships among phenomena, and use evidence to support their reasoning. Developing such understanding requires learning experiences that extend beyond factual recall and provide opportunities for students to activate prior knowledge, investigate meaningful problems, discuss alternative explanations, receive feedback, reflect on their thinking, and apply concepts in relevant situations. Recent research indicates that conceptual understanding in science is associated with how learners organize and relate knowledge, while students' conceptions of science and science identity may also contribute to conceptual development (Vaiopoulou et al., 2023; Bodas & Kelemen, 2026). Differences in students' conceptual profiles further suggest that understanding may develop unevenly across scientific domains, reflecting variation in how learners construct and integrate scientific knowledge. When science learning is predominantly organized around teacher explanations and information recall, students may acquire factual knowledge while experiencing difficulties in explaining conceptual relationships, providing scientific reasoning, or applying knowledge to unfamiliar situations.

In this context, deep learning has emerged as a relevant pedagogical orientation for supporting more substantive forms of learning. In this study, deep learning refers specifically to a pedagogical orientation that integrates mindful learning, meaningful learning, and joyful learning to support students' active engagement, conceptual meaning-making, reflection, and application of knowledge. This conceptualization distinguishes deep learning from the *deep approach to learning* described in the learning-approaches literature and from deep learning in artificial intelligence. Rather than emphasizing the passive reception and reproduction of information, deep learning emphasizes meaningful engagement with knowledge, authentic experiences, interaction, reflection, and the use of learning to address relevant problems. Fullan and Langworthy (2014) conceptualize deep learning as learning that enables students to integrate knowledge, skills, and values to address meaningful challenges. From this perspective, deep learning concerns not only what students learn but also how they construct meaning, engage with others, reflect on their learning, and use knowledge in meaningful contexts.

Empirical research has demonstrated that deep learning can be supported through pedagogical approaches that require students to construct solutions, integrate knowledge, and engage in authentic problem solving. Design-based learning, for example, has been shown to support deep learning by encouraging students to apply knowledge, reflect on learning processes, and develop higher-order competencies (Weng et al., 2023). Recent reviews further indicate that deep learning involves the integration of cognitive engagement, meaningful knowledge construction, learner agency, and contextual application rather than the simple acquisition of information (Chen & Singh, 2024). In addition, recent empirical evidence suggests that deep learning is influenced by interactions among learner engagement, self-efficacy, and teacher–student interaction, indicating that deep learning emerges within supportive pedagogical environments rather than through instructional activities alone (Shi & Lan, 2024). However, these studies provide limited insight into how deep learning is enacted through concrete classroom interactions and how its pedagogical dimensions contribute to the construction and refinement of conceptual understanding, particularly in elementary science learning.

The pedagogical orientation of deep learning is consistent with established perspectives on learning and knowledge construction. Marton and Säljö (1976) distinguished deep approaches to learning from surface approaches by emphasizing the search for meaning and the establishment of relationships among ideas. Constructive alignment further emphasizes coherence among learning outcomes, learning activities, and assessment in supporting intended learning outcomes (Biggs, 1987; Biggs & Tang, 2011). Constructivist and sociocultural perspectives similarly view learning as an active process in which learners construct and reorganize knowledge through cognitive engagement and social interaction (Piaget, 1952; Vygotsky, 1978). Scaffolding provides additional insight into how teacher guidance and feedback can support learners in developing understanding that may initially be beyond their

independent capabilities (Wood et al., 1976). Together, these perspectives suggest that conceptual understanding develops through an interconnected process involving prior knowledge, active meaning-making, social interaction, instructional guidance, feedback, and reflection. Nevertheless, these perspectives have generally been discussed as complementary theoretical explanations rather than integrated into an empirically grounded account of how such processes operate within deep learning in elementary classrooms.

Within the Indonesian educational context, the implementation of deep learning has increasingly emphasized three interconnected dimensions: mindful learning, meaningful learning, and joyful learning. Mindful learning concerns students' attention and awareness during the learning process; meaningful learning involves connecting new knowledge with prior knowledge and relevant experiences; while joyful learning emphasizes supportive, engaging, and positive learning conditions that encourage active participation. These dimensions can be related to established perspectives on meaningful learning, mindfulness, motivation, and cognitive processing (Ausubel, 1968; Langer, 1989; Mayer, 2002; Ryan & Deci, 2000). They are also consistent with experiential learning theory, which emphasizes that meaningful understanding develops through cycles of concrete experience, reflective observation, conceptualization, and active application (Kolb, 1984). Furthermore, joyful and supportive learning environments are closely related to student engagement, which involves behavioral, emotional, and cognitive dimensions of students' involvement in learning activities (Fredricks et al., 2004). However, the presence of these principles alone does not explain how conceptual understanding is constructed in classroom practice. Their educational significance depends on how they are enacted through learning activities, classroom interactions, teacher facilitation, formative assessment, feedback, reflection, and opportunities to apply knowledge.

Existing research on science learning has demonstrated the importance of phenomenon-based learning, modeling, inquiry, and instructional support in developing students' conceptual understanding and scientific reasoning (Helsel et al., 2022; Oh et al., 2022; Heppt et al., 2023; Corrigan et al., 2025). For example, research involving elementary students indicates that engagement with scientific phenomena through STEM- and STEAM-oriented learning can support conceptual understanding by connecting disciplinary knowledge with active investigation and explanation (Corrigan et al., 2025). Similarly, inquiry-based learning accompanied by appropriate instructional support has been associated with students' science content knowledge and academic language development (Heppt et al., 2023). Recent evidence also indicates that formative assessment integrated with instructional feedback contributes to students' monitoring and regulation of learning processes by helping them identify gaps in understanding, evaluate their thinking, and refine their responses during science instruction (Gedikli & Buldur, 2022). These findings reinforce the importance of examining not only which instructional approaches are used but also the pedagogical processes through which students construct, examine, revise, and apply conceptual knowledge.

Conceptual understanding is also shaped by how learners interpret, organize, and revise their initial conceptions. Research on students' conceptions of the greenhouse effect demonstrates that scientific understanding may involve complex and partially coherent conceptual structures rather than a single, consistently organized system of knowledge (Schubatzky et al., 2024). Likewise, research on modeling with data shows that students may revise their mechanistic reasoning and conceptual understanding as they engage with evidence and construct explanatory models (Fuhrmann et al., 2025). These findings indicate that conceptual understanding develops through processes of reasoning, interpretation, examination, and revision rather than through the simple accumulation of factual information. However, much of the existing research has examined particular instructional approaches, specific scientific concepts, or individual aspects of conceptual learning. Comparatively less attention has been given to how deep learning is enacted as an interconnected pedagogical system in elementary classrooms and how mindful learning, meaningful learning, and joyful learning function together with teacher facilitation, peer interaction, formative feedback, reflection, and contextual application in supporting conceptual understanding.

This issue is particularly relevant in Indonesia, where students continue to face challenges in competencies requiring reasoning, interpretation, and the application of knowledge. The Programme for International Student Assessment (PISA) 2022 results indicate that Indonesian students performed below the OECD average in reading, mathematics, and science, domains that require students to interpret information, reason about evidence, and apply knowledge to different situations (OECD, 2023). Although PISA results cannot be used to explain classroom-level processes directly, they highlight the broader importance of examining pedagogical practices that may support students in moving beyond information acquisition toward deeper conceptual understanding and meaningful knowledge use.

The need to examine these processes was also evident in the preliminary context of the present study at SD Negeri 13 Kubu, Kubu Raya Regency. Preliminary observations indicated that IPAS learning was predominantly organized around teacher explanations, while students had relatively limited opportunities to ask questions, express ideas, and connect learning content with everyday experiences. Preliminary formative assessment further indicated that students were generally able to respond to factual questions but experienced difficulties when asked to explain scientific reasoning, establish relationships among concepts, or apply IPAS knowledge to authentic situations. This context provided a relevant setting for examining how deep learning was enacted in classroom practice and how students' conceptual understanding was constructed and refined through learning activities and interactions.

The research gap addressed by this study therefore concerns not whether deep learning can improve students' learning outcomes, but how its pedagogical dimensions are enacted and interconnected in the formation of conceptual understanding. Existing theoretical perspectives explain important elements of this process, including the role of prior knowledge in meaningful learning, cognitive restructuring in conceptual development, social interaction in knowledge construction, scaffolding in guided learning, and reflection in examining and refining understanding (Ausubel, 1968; Dewey, 1933; Piaget, 1952; Vygotsky, 1978; Wood et al., 1976). Empirical research further indicates that conceptual understanding in science develops through processes involving reasoning, modeling, inquiry, instructional support, formative feedback, and the revision of initial conceptions (Fuhrmann et al., 2025; Heppt et al., 2023; Schubatzky et al., 2024). However, these perspectives and findings have rarely been integrated into an empirically grounded explanation of how deep learning operates as an interconnected pedagogical process within elementary IPAS classrooms. In particular, the functional relationships among mindful learning, meaningful learning, and joyful learning, and their interaction with concrete pedagogical mechanisms for conceptual development, remain insufficiently understood.

Addressing this gap, the present study examines the implementation of deep learning in elementary IPAS learning and identifies the pedagogical processes through which students construct and refine conceptual understanding. Particular attention is given to how mindful learning, meaningful learning, and joyful learning are enacted in classroom practice and how these dimensions interact with prior knowledge activation, collaborative meaning-making, teacher scaffolding, formative feedback, reflection, and contextual application. Rather than testing the causal effectiveness of deep learning or measuring statistically significant changes in learning outcomes, the study seeks to develop an empirically grounded explanation of the pedagogical processes through which conceptual understanding is constructed and refined within a natural elementary classroom setting.

The study makes three contributions. First, it contributes theoretically by extending discussion of deep learning from its emphasis on competencies and learning outcomes toward the pedagogical processes associated with conceptual understanding formation. Second, it contributes empirically by providing a process-oriented account derived from multiple qualitative sources, including classroom observations, semi-structured interviews, and instructional documents. Third, it contributes conceptually and practically by proposing an empirically grounded Systemic Deep Learning Model for Conceptual Understanding Formation that explains the complementary functions of mindful learning, meaningful learning, and joyful

learning within a broader system of teacher facilitation, collaborative meaning-making, formative feedback, reflection, and contextual application.

Accordingly, this study aims to examine how deep learning is implemented in elementary IPAS learning, identify the pedagogical processes through which students construct and refine conceptual understanding, and propose an empirically grounded conceptual model explaining the functional relationships among mindful learning, meaningful learning, joyful learning, and the pedagogical mechanisms involved in conceptual development. The study specifically addresses the following research questions: (1) How is deep learning implemented in elementary IPAS learning? (2) Through what pedagogical processes do students construct and refine conceptual understanding? and (3) How can the relationships among the dimensions of deep learning and these pedagogical processes be conceptualized into an empirically grounded model of conceptual understanding formation?

METHODS

Research Approach and Design

This study employed a qualitative approach using a single-case study design to examine how deep learning was implemented in elementary IPAS learning and how students developed conceptual understanding through classroom processes. The study focused on the enactment of three deep learning principles mindful learning, meaningful learning, and joyful learning—and examined how these principles were reflected in students' processes of constructing, connecting, applying, and reflecting on scientific concepts.

A single-case study design was selected because it enables researchers to investigate contemporary educational phenomena within their real-life contexts while maintaining attention to the complexity of interactions among instructional practices, participants, and contextual conditions (Stake, 1995; Yin, 2018). The case in this study was bounded by the implementation of deep learning in Grade 5 IPAS learning at SD Negeri 13 Kubu, Kubu District, Kubu Raya Regency, Indonesia. The instructional context focused on environmental issues, particularly waste management, as this topic provided opportunities for students to relate scientific concepts to everyday experiences and authentic problems.

The case boundaries were defined through four dimensions: (1) participants involved in Grade 5 IPAS learning, (2) the instructional setting of one elementary school, (3) the learning topic concerning waste management and environmental issues, and (4) the period of data collection during the second semester of the 2025/2026 academic year. These boundaries allowed the study to generate an in-depth understanding of how deep learning processes occurred within a specific educational context.

Research Site and Participants

The study was conducted during the second semester of the 2025/2026 academic year in a Grade 5 classroom at SD Negeri 13 Kubu, Kubu District, Kubu Raya Regency, Indonesia. Data collection was conducted over approximately three to four weeks. The research site was selected purposively because the classroom context provided a relevant setting for examining the implementation of deep learning principles and the development of students' conceptual understanding through contextual IPAS instruction.

The participants consisted of 19 individuals, including one Grade 5 teacher, 17 Grade 5 students, and one school principal. All 17 students participated in classroom observations, while six students were purposively selected for individual interviews to obtain richer accounts of their learning experiences, understanding, and reflections. The selection considered variation in academic performance and classroom participation based on teacher recommendations and preliminary observations (Creswell & Poth, 2018).

The Grade 5 teacher served as the primary informant regarding instructional planning, classroom implementation, facilitation strategies, assessment practices, feedback, and reflection activities. The interviewed students provided perspectives regarding their learning experiences, difficulties, conceptual development, and application of scientific knowledge. The school principal contributed contextual information related to institutional support and school-level conditions influencing learning implementation.

The study examined two interconnected dimensions: (1) the implementation of deep learning through mindful learning, meaningful learning, and joyful learning; and (2) students' conceptual understanding as reflected in their abilities to explain concepts, establish relationships among concepts, provide scientific reasoning, reflect on learning experiences, and apply knowledge in relevant contexts.

Researcher's Role and Instruments

In accordance with qualitative inquiry, the researcher functioned as the primary instrument in data collection, analysis, and interpretation (Creswell & Poth, 2018). The researcher conducted classroom observations, interviews, and document analysis; organized and interpreted empirical evidence; and developed themes based on patterns identified across multiple data sources.

Reflexivity was maintained throughout the research process through field notes and reflective records documenting observations, analytical decisions, emerging interpretations, and potential researcher assumptions (Creswell & Poth, 2018). These reflective practices helped maintain transparency regarding the researcher's role in constructing interpretations from the collected data.

Supporting instruments included an observation protocol, semi-structured interview guide, document analysis framework, and field notes. The observation protocol focused on teacher facilitation, student engagement, classroom interaction, and observable indicators of mindful learning, meaningful learning, and joyful learning. The interview guide explored participants' experiences, perceptions of learning activities, conceptual understanding, reflection processes, and application of knowledge. The document analysis framework was used to examine instructional planning, learning activities, assessment practices, and student learning products. The instruments were reviewed by two experts in elementary education to evaluate their alignment with research objectives, clarity, and appropriateness for the study context. Feedback from the experts was incorporated before the instruments were implemented.

Data Collection

Data were collected through classroom observations, semi-structured interviews, and document analysis. The use of multiple data sources enabled the researcher to examine the phenomenon from different perspectives and supported the comparison of evidence across sources (Stake, 1995; Yin, 2018). Data collection and preliminary analysis were conducted iteratively, allowing emerging interpretations to guide subsequent data collection.

Classroom Observation

Six classroom observations were conducted, with each session lasting 2 × 35 minutes. Observations focused on learning activities involving conceptual understanding, including processes of understanding, applying, and reflecting. Particular attention was given to the implementation of mindful learning, meaningful learning, and joyful learning through students' engagement with contextual problems, activation of prior knowledge, collaborative discussion, explanation and reasoning, teacher scaffolding, feedback, reflection, and application of concepts. The researcher recorded classroom interactions, student responses, teacher instructional strategies, and contextual events. Field notes were used to document significant learning episodes, interaction patterns, emerging analytical categories, and evidence related to students' conceptual development.

Semi-Structured Interviews

Semi-structured interviews were conducted after classroom observations with one Grade 5 teacher, six selected students, and the school principal. The teacher interview explored instructional planning, implementation of deep learning principles, strategies for supporting conceptual understanding, assessment practices, feedback, and reflection. Student interviews focused on learning experiences, understanding of IPAS concepts, challenges encountered, teacher and peer support, and the application of concepts beyond classroom activities. The principal interview examined school-level support and contextual factors influencing instructional implementation. All interviews were audio-recorded with participants' consent and transcribed verbatim. The transcripts were organized and coded using NVivo 15 as a supporting tool for qualitative data management.

Document Analysis

Document analysis involved examination of the Grade 5 IPAS teaching module, student worksheets (LKPD), teacher reflection notes, classroom activity documentation, and formative assessment records. The documents were analyzed to identify alignment among learning objectives, instructional activities, assessment practices, and reflection processes. Particular attention was given to students' written explanations, classification of waste, scientific reasoning, revisions of initial responses, reflection entries, and proposed solutions to environmental issues. Document evidence was used to complement observational and interview data and to examine consistency between classroom processes, participant accounts, and students' learning products.

Data Analysis

Data analysis followed the interactive qualitative analysis model proposed by Miles et al. (2014), consisting of data condensation, data display, and conclusion drawing and verification. Analysis was conducted throughout the research process and continued after data collection was completed.

Initially, observation records, interview transcripts, and documents were reviewed repeatedly to develop an overall understanding of the case. Subsequently, relevant data segments were coded according to aspects related to deep learning implementation and students' conceptual understanding. Related codes were then compared and grouped into broader categories representing recurring patterns across data sources. The categories were further examined to identify relationships among learning processes, classroom interactions, and students' conceptual development. The final themes were constructed through continuous comparison between empirical evidence and emerging interpretations.

NVivo 15 was used as a supporting tool to organize, retrieve, and manage qualitative data. Interpretation remained the responsibility of the researcher through systematic comparison across observations, interviews, and documents. Evidence from different sources was examined to identify convergence and divergence, ensuring that themes were supported by sufficient empirical evidence.

Trustworthiness

The trustworthiness of this study was established through credibility, transferability, dependability, and confirmability criteria (Lincoln & Guba, 1985).

Credibility was strengthened through methodological and source triangulation. Methodological triangulation involved comparing evidence from classroom observations, interviews, and document analysis. Source triangulation involved comparing perspectives from teachers, students, and school leaders. Member checking was conducted by discussing preliminary interpretations with relevant participants to ensure that interpretations represented their experiences accurately.

Transferability was supported through detailed descriptions of the research context, participants, instructional processes, and case boundaries, allowing readers to assess the applicability of findings to similar educational contexts. Dependability was enhanced through systematic documentation of research procedures, including data collection processes, coding procedures, analytical decisions, and theme development. An audit trail was maintained throughout the research process. Confirmability was supported through maintaining analytical records, reflexive notes, and evidence-based interpretation. These procedures ensured traceability between empirical data, analytical processes, and research conclusions (Lincoln & Guba, 1985).

Ethical Considerations

The study was conducted after obtaining permission from the participating school. Before data collection, participants were informed about the research objectives, procedures, confidentiality measures, voluntary participation, and their right to withdraw from the study. Because elementary students participated in the research, parental or guardian consent and student assent were obtained before interviews and data collection activities were conducted. Participants' identities were protected through anonymization. The teacher was identified using the code G1, while interviewed students were represented using codes such as S4, S5, S7, S8,

S12, and S14. Research materials, including audio recordings, transcripts, field notes, and documents, were stored securely and used only for academic purposes.

RESULTS AND DISCUSSION

Implementation of Deep Learning in Elementary IPAS Learning

Analysis of classroom observations, interviews, and learning documents showed that deep learning was implemented through the integration of learning design, student activities, teacher facilitation, formative assessment, and reflection. The teaching module, student worksheets (LKPD), and formative assessment documents indicated that learning objectives extended beyond factual knowledge of waste types and characteristics. Students were expected to explain the basis for waste classification, relate concepts to everyday experiences, and use their understanding to respond to waste-management problems.

The observed learning activities were organized around three processes: understanding, applying, and reflecting. During the understanding process, the teacher introduced contextual problems related to waste management in the students' immediate environment. Classroom observations showed that students responded more actively to questions connected with their own experiences at home and school. Students were able to relate the problem to familiar situations, although their initiative to formulate critical questions independently was less evident.During the applying process, students worked collaboratively to identify and classify waste according to its characteristics and develop possible solutions to waste-management problems. Observations showed that students compared answers, provided reasons for their classifications, and negotiated different interpretations during group discussions. The teacher primarily acted as a facilitator by posing guiding questions and providing feedback rather than immediately supplying answers.

Evidence from the LKPD showed that most groups were able to classify waste and provide relevant reasons based on its characteristics. Some responses were revised after group discussions and classroom feedback. These revisions indicated that students had opportunities to reconsider their initial understanding and refine their explanations during the learning process.

During the reflecting process, students presented their group findings, responded to feedback from the teacher and peers, and documented what they had understood and what they still found difficult. Reflection records showed that students were able to restate concepts in their own words and relate them to waste-management practices at home and school. One student stated: “Now I separate plastic waste from leaves at home because they need to be processed differently.” (S14) Another student explained: “I remind my younger sibling not to mix all types of waste in one place.” (S5) The teacher's account supported the observation and documentary evidence. The teacher explained that students' everyday experiences were deliberately used as an entry point for introducing scientific concepts: “I usually start by asking questions about their waste-disposal habits at home or at school. From there, they begin recalling their own experiences before moving on to the lesson material.”(G1)

Across the three data sources, three recurring patterns were identified. First, learning objectives, activities, and formative assessment were consistently directed toward conceptual understanding rather than factual recall alone. Second, students were provided with opportunities to construct and refine understanding through contextual exploration, collaborative discussion, practice, feedback, and reflection. Third, the teacher's facilitative role created opportunities for students to examine their initial ideas and develop more elaborated explanations.

Overall, the findings indicate that deep learning in this case was enacted through the integration of learning design, collaborative activity, teacher facilitation, formative feedback, and reflection. The three processes of understanding, applying, and reflecting provided an organizing structure for classroom activities, while the interaction among these elements created opportunities for students to develop conceptual understanding.

Pedagogical Mechanisms Supporting the Development of Conceptual Understanding

Cross-analysis of observation, interview, and documentary data identified five interrelated mechanisms associated with the development of students' conceptual understanding: activation of prior knowledge, construction of meaning through interaction, refinement of understanding through scaffolding and feedback, metacognitive reflection, and application of concepts in different contexts. These mechanisms did not operate as separate or strictly sequential stages but interacted throughout the learning process, with students sometimes revisiting earlier ideas when encountering new information, receiving feedback, or reflecting on their understanding.

The process was initially supported by the activation of prior knowledge through contextual problems concerning waste management. Classroom observations showed that students frequently drew on experiences at home and school when responding to the teacher's questions. One student stated, "When I was asked about waste at home, I immediately remembered that plastic waste was often mixed with leaves. So, I became curious about why they should be separated."(S4). This response illustrates how a familiar experience became a reference point for engaging with the concept of wa ste classification. Rather than encountering the topic solely as new information, the student used an existing experience to interpret and question the problem presented in the classroom. This pattern was also evident in students' subsequent participation in discussions and problem-solving activities, indicating that prior experience functioned as a resource for engaging with new conceptual content.

The activation of prior knowledge was followed by the construction of meaning through discussion and collaborative problem solving. Students classified waste, explained their reasoning, compared answers, and responded to their peers' arguments. The teacher described the role of discussion as follows: "If I explain everything directly, they only listen. But when they discuss it themselves, they usually understand better because they give each other reasons." (G1). A student similarly explained, "When my friend explained why leaf waste is considered organic, I finally understood because I had previously thought that all waste was the same." (S8). The LKPD further showed that most groups were able to classify waste and provide reasons based on its characteristics. Taken together, these data indicate that students' understanding was constructed through the interaction of prior experience, peer discussion, explanation, and comparison of ideas rather than through the reception of information alone.

The development of understanding also involved the examination and revision of initial explanations. During classroom interactions, the teacher used guiding questions to encourage students to reconsider answers that were incomplete or inaccurate. The teacher stated, "When an answer is not quite correct, I usually ask another question so that students can think for themselves rather than simply giving them the answer." (G1). One student described a change in understanding: "At first, I incorrectly classified the waste, but after my friend and the teacher explained it, I understood the reason." (S12). The LKPD contained revisions to several initial answers following classroom discussions, while reflection records showed that students subsequently provided more appropriate explanations of waste classification. These findings indicate that conceptual understanding was refined through a combination of teacher scaffolding, peer interaction, formative feedback, and opportunities to reconsider initial ideas. The teacher's role was therefore not limited to correcting errors but also involved creating conditions in which students could examine their own reasoning and progressively reorganize their understanding.

This process of refinement was complemented by metacognitive reflection. Students were asked to identify what they had understood and which aspects remained difficult. One student stated, "Setelah menulis refleksi saya jadi tahu kalau masih bingung membedakan beberapa jenis sampah." (S7). Reflection records similarly showed that students could identify concepts they had understood as well as aspects that remained unclear. These findings suggest that reflection provided an opportunity for students to review their understanding and recognize areas requiring further clarification. However, the evidence should not be interpreted as demonstrating a measurable increase in metacognitive ability, as metacognition was not directly assessed through a standardized or independent measure. Rather, reflection functioned

as a pedagogical practice that enabled students to make their understanding and remaining difficulties more explicit.

The development of conceptual understanding was also evident in students' application of concepts beyond the immediate classroom activity. Group work demonstrated that students could formulate possible solutions to waste-management problems in the school environment. Interview data further indicated that some students reported applying the concepts at home: "Now I separate plastic waste from leaves at home because they need to be processed differently." (S14). These findings suggest that students began to apply concepts developed during classroom learning to contexts beyond the immediate instructional activity. However, given the qualitative evidence available, this pattern is interpreted as the application of concepts across different contexts rather than definitive evidence of far transfer, which would require systematic examination across multiple unfamiliar situations. The findings therefore indicate the emergence of contextual application while maintaining appropriate caution regarding the extent of knowledge transfer.

Across the data sources, these mechanisms were interconnected rather than strictly linear. Prior knowledge provided a foundation for engaging with the problem, while dialogue and collaboration enabled students to compare and negotiate meanings. Scaffolding and formative feedback created opportunities to examine and revise initial understandings, and reflection allowed students to identify what they understood and what remained unclear. Application then provided opportunities to use the emerging understanding in relevant situations, which could in turn generate new experiences and return students to earlier stages of questioning and conceptual examination. The process was therefore recursive, with students revisiting and refining their understanding as they encountered new information, alternative explanations, feedback, and contextual demands.

Overall, the findings indicate that conceptual understanding developed through the interaction of prior knowledge, collaborative meaning-making, teacher scaffolding, formative feedback, reflection, and contextual application. No single activity or pedagogical component appeared to independently account for the development of understanding. Instead, the evidence points to a connected pedagogical process in which students constructed meaning, examined and revised their initial ideas, reflected on their understanding, and used emerging concepts in relevant contexts. This process provides an empirical basis for understanding conceptual development within deep learning implementation as a dynamic and recursive process rather than as the direct outcome of a single instructional strategy.

Systemic Model of Deep Learning for Conceptual Understanding Formation

The synthesis of findings from the first two themes identified distinct but interconnected roles for mindful learning, meaningful learning, and joyful learning in supporting the development of conceptual understanding. The data did not indicate that these three dimensions functioned as separate or sequential stages. Instead, they operated as complementary pedagogical dimensions within the same learning environment, interacting with classroom activities, teacher facilitation, peer interaction, formative assessment, feedback, reflection, and opportunities to apply knowledge.

Mindful learning was evident in students' attention to the learning problem, activation of prior experiences, and awareness of their own understanding. Contextual questions concerning waste management directed students' attention toward problems that were familiar and relevant to their daily lives. This contextual orientation provided a basis for students to connect previous experiences with new information and to become more attentive to the concepts being examined. In this study, mindful learning therefore functioned primarily as a condition supporting cognitive readiness and focused engagement with the learning problem rather than as an independent mechanism that directly produced conceptual understanding.

Meaningful learning emerged more explicitly when students connected their experiences with new concepts through discussion, explanation, argumentation, collaboration, and problem solving. The classification activity required students not only to identify types of waste but also to explain the reasons underlying their classifications. When initial explanations were challenged, incomplete, or inconsistent with the characteristics of the materials being examined,

students had opportunities to reconsider and refine their understanding through peer interaction and teacher feedback. Meaningful learning therefore functioned as the primary pedagogical process through which students constructed and refined conceptual meaning by connecting prior knowledge with new information and by examining relationships among concepts through active engagement.

Joyful learning was reflected in an active, collaborative, and relatively supportive classroom environment. Students participated in group discussions, practical activities, presentations, and exchanges of ideas. Observational data indicated that students were willing to express their opinions, respond to questions, receive corrections, and reconsider their answers during classroom interactions. In this study, joyful learning is therefore positioned as an enabling condition that supported students' sustained engagement in the cognitive and social processes involved in learning. However, the available data do not directly demonstrate that joyful learning independently increased students' intrinsic motivation or caused improvements in conceptual understanding. Rather, the findings indicate that a supportive and enjoyable learning environment coincided with students' active participation in activities that facilitated meaning construction, reflection, and conceptual refinement. Accordingly, joyful learning is interpreted cautiously as a contextual condition that enables participation rather than as a direct causal mechanism of conceptual development.

The functioning of these three dimensions was supported by several concrete pedagogical processes. Teacher facilitation provided guiding questions and feedback that encouraged students to reconsider their initial ideas rather than simply receive correct answers. The LKPD provided structured opportunities for students to classify materials, explain their reasoning, revise initial responses, and formulate solutions to environmental problems. Formative assessment provided information about students' developing understanding, while feedback enabled students to identify and address misconceptions or incomplete explanations. Previous studies have similarly emphasized that formative assessment becomes more effective when accompanied by timely feedback and opportunities for students to revise their conceptual understanding throughout the learning process (Gedikli & Buldur, 2022). Collaborative activities further allowed students to compare perspectives, explain their reasoning, and negotiate meanings with peers. These processes connected the dimensions of deep learning with observable classroom practices and helped translate the broader principles of mindful, meaningful, and joyful learning into mechanisms through which conceptual understanding could be constructed and refined.

Based on this synthesis, the study proposes the Systemic Deep Learning Model for Conceptual Understanding Formation. The model conceptualizes the development of conceptual understanding as an integrated process involving cognitive, social, metacognitive, and contextual dimensions. Within this model, mindful learning supports students' attention, awareness, and cognitive readiness to engage with learning problems; meaningful learning functions as the primary mechanism through which students construct and refine conceptual meaning; metacognitive reflection provides opportunities to review and evaluate developing understanding; and contextual application enables students to use emerging concepts beyond the immediate learning activity. Joyful learning operates across these processes as an enabling condition that supports active, safe, collaborative, and sustained engagement.

The model does not position mindful learning, meaningful learning, and joyful learning as three sequential stages. Instead, they are conceptualized as dimensions with different but complementary functions within an integrated pedagogical system. Mindful learning can orient students toward relevant problems and activate attention to prior experiences, while meaningful learning supports the construction and refinement of conceptual understanding through interaction and problem solving. Reflection allows students to examine the adequacy of their understanding, while application provides opportunities to use concepts in relevant situations. Throughout these processes, joyful learning contributes to a supportive environment in which students are more willing to participate, express ideas, make errors, receive feedback, and revise their thinking. The relationships among these dimensions are therefore dynamic and

recursive rather than linear, as students may return to earlier ideas when they encounter new information, conflicting explanations, or difficulties in applying concepts.

The central empirical contribution of the study lies in identifying a systemic relationship between the dimensions of deep learning and the pedagogical processes associated with conceptual understanding. Rather than treating deep learning solely as an approach expected to improve learning outcomes, the findings provide a process-oriented explanation of how conceptual understanding may be constructed and refined through the interaction of cognitive readiness, meaning-making, conceptual refinement, metacognitive reflection, contextual application, and supportive learning conditions. The proposed model therefore emphasizes that conceptual understanding is not attributable to a single instructional strategy or to any one dimension of deep learning. Instead, it develops through the functional connection of multiple pedagogical processes within the classroom context. This formulation also maintains an appropriate interpretive boundary: the model represents an empirically grounded explanation of relationships observed within the case rather than a causal model demonstrating that each component independently produces conceptual understanding.

DISCUSSION

The findings show that deep learning in elementary IPAS was enacted through the coordinated organization of learning objectives, classroom interaction, teacher facilitation, assessment, reflection, and opportunities for application. Students were expected to classify waste, explain the basis of their classifications, relate scientific concepts to everyday experiences, reconsider initial explanations, and respond to environmental problems. These practices indicate that the contribution of deep learning lay less in the use of particular activities than in how those activities were organized around conceptual purposes. This extends previous research linking deep learning with meaningful knowledge construction, learner engagement, contextual application, and higher-order competencies (Chen & Singh, 2024; Weng et al., 2023) by showing how these broad characteristics were enacted through observable classroom processes.

The coherence among learning objectives, activities, and assessment was central to this process. The teaching module, LKPD, formative assessment, and reflection activities required students to explain, connect, and apply concepts rather than recall information alone. This pattern reflects constructive alignment, in which intended learning outcomes, learning activities, and assessment are designed to work toward shared learning purposes (Biggs, 1987; Biggs & Tang, 2011). In the present case, group discussion, classification tasks, and practical activities supported conceptual development because students had to justify responses, compare interpretations, and revise explanations. Thus, the presence of active learning was not sufficient in itself; its contribution depended on whether classroom activities required students to work with relationships among concepts.

Students' prior experiences provided an entry point for this process. Waste-management problems drawn from home and school enabled students to interpret new concepts through familiar situations. This finding is consistent with Ausubel's (1968) view that meaningful learning involves substantive connections between new knowledge and existing cognitive structures and with experiential perspectives linking experience, reflection, conceptualization, and application (Dewey, 1933; Kolb, 1984). However, the evidence indicates that prior knowledge became productive only when students were encouraged to examine it. Initial ideas were tested through discussion, explanation, comparison, and feedback. Meaningful learning therefore involved more than contextualizing content; it required students to reconsider whether their existing interpretations adequately explained the problem. This process positioned meaningful learning as a mechanism for conceptual development rather than simply a strategy for increasing relevance or interest.

Social interaction provided the setting in which students' reasoning became available for examination. Students compared classifications, explained their choices, responded to peers, and reconsidered their interpretations. This pattern is consistent with sociocultural perspectives emphasizing interaction in knowledge construction (Vygotsky, 1978) and constructivist

accounts of learners as active participants in reorganizing knowledge (Piaget, 1952). The findings suggest that peer interaction contributed to conceptual development because students were required to externalize and compare their reasoning. Teacher facilitation strengthened this process through questions and feedback that directed attention toward the basis of students' responses. The teacher therefore functioned less as the sole provider of correct answers and more as a facilitator who structured opportunities for students to examine and improve their reasoning.

Revision was a further feature of conceptual development. Incomplete or inaccurate explanations were treated as starting points for additional reasoning. Through guiding questions, peer discussion, and feedback, students were given opportunities to reconsider their initial responses. This pattern is consistent with the role of scaffolding in supporting learners' progression toward more independent understanding (Wood et al., 1976). It also clarifies the role of formative assessment: feedback became instructionally meaningful when students could use it to revise their responses. Evidence from revised LKPD entries and subsequent explanations suggests that assessment operated as part of the learning process rather than solely as a means of judging correctness. This interpretation is consistent with research indicating that formative assessment and feedback can help students identify gaps and refine their understanding during science learning (Gedikli & Buldur, 2022). Conceptual change in this case therefore appeared to involve progressive reorganization of initial ideas in response to interaction, feedback, and new explanations (Schubatzky et al., 2024; Fuhrmann et al., 2025).

Reflection complemented this process by directing students' attention to the state of their own understanding. Students identified concepts they understood and aspects that remained difficult, making uncertainties available for further clarification. The evidence, however, does not demonstrate an increase in metacognitive ability because metacognition was not directly assessed through an independent measure. Reflection is therefore interpreted as a pedagogical practice that enabled students to review their understanding and identify remaining difficulties, rather than as evidence of measurable metacognitive development.

Application extended learning into situations beyond the immediate instructional task. Students proposed responses to waste-management problems at school, and some reported using waste-classification concepts at home. These instances indicate contextual use of knowledge but do not establish far transfer, which would require systematic evidence across substantially different or unfamiliar situations. The application observed in this study is more appropriately understood as the use of emerging concepts in authentic and relevant contexts. Such use may nevertheless provide additional experiences through which students can reconsider the adequacy of their understanding and generate further questions, consistent with experiential accounts of learning (Dewey, 1933; Kolb, 1984).

The findings also clarify the distinct functions of mindful, meaningful, and joyful learning. These dimensions did not operate as sequential stages. Mindful learning supported students' attention and readiness to engage with relevant problems and experiences (Langer, 1989). Meaningful learning served as the principal process through which students connected prior experiences with new concepts and reorganized their understanding (Ausubel, 1968). Joyful learning operated as an enabling condition by supporting a classroom environment in which students could participate, express ideas, receive feedback, and revise their responses. The evidence does not demonstrate that joyful learning independently caused gains in conceptual understanding or intrinsic motivation. Rather, its role was evident in sustaining students' participation in the cognitive and social activities through which understanding was developed, consistent with research on supportive learning environments and engagement (Ryan & Deci, 2000; Fredricks et al., 2004).

These relationships form the basis of the proposed Systemic Deep Learning Model for Conceptual Understanding Formation. The model represents conceptual development as a connected process in which attention and prior experience initiate engagement with a problem; interaction, scaffolding, and feedback support the examination and revision of emerging ideas; reflection enables students to identify unresolved difficulties; and contextual application provides opportunities to use and further examine developing knowledge. Because application

can generate new experiences or reveal unresolved problems, the process may return students to earlier stages of questioning and examination. The resulting pattern is therefore recursive rather than sequential.

The model's systemic character derives from the interdependence of these mechanisms. Prior knowledge may provide a starting point but does not ensure conceptual change; interaction can expose alternative ideas but may require teacher guidance; feedback can identify weaknesses but requires opportunities for revision; and application can extend knowledge but may not deepen understanding without further examination. Conceptual development is therefore associated with the coordination of these processes rather than with any single instructional component. Within this system, mindful learning provides attentional orientation, meaningful learning drives conceptual construction and refinement, and joyful learning supports sustained participation.

The model contributes primarily at the explanatory level. It offers an empirically grounded account of how the three dimensions of deep learning may operate in relation to specific pedagogical mechanisms within an elementary IPAS classroom. It does not establish independent causal effects or statistical generalizability beyond the case. Instead, it extends discussions of deep learning that have emphasized meaningful engagement, learner agency, and competency development (Fullan & Langworthy, 2014; Fullan et al., 2018) by specifying the classroom processes through which these principles may be connected to conceptual development. The model consequently shifts attention from whether deep learning is present to how its dimensions are enacted through interaction, scaffolding, feedback, reflection, and application.

For elementary IPAS instruction, the findings indicate that deep learning requires deliberate coordination between conceptual goals and classroom processes. Teachers need to use students' experiences as starting points for inquiry, require explanations rather than simple answers, structure interaction so that reasoning can be compared, provide feedback that leads to revision, and incorporate reflection and contextual application into the learning process. The teacher's role is consequently to organize and guide the conditions under which students can examine and develop their understanding. Deep learning, in this context, is most meaningful when its principles are translated into a coherent pedagogical system that connects attention, meaning-making, interaction, revision, reflection, and application.

CONCLUSION

This study concludes that deep learning in elementary IPAS learning operates as an integrated pedagogical system rather than as a set of isolated instructional practices. Conceptual understanding emerged through the interaction of pedagogical conditions and processes that enabled students to construct, examine, revise, and apply knowledge. Within this system, mindful learning, meaningful learning, and joyful learning served distinct but complementary functions. Mindful learning supported students' attention and readiness to engage with learning problems, meaningful learning provided the main process for constructing and refining conceptual understanding, and joyful learning created a supportive environment for sustained participation. Their contribution was therefore interconnected with the pedagogical processes through which students engaged with ideas and developed their understanding. The Systemic Deep Learning Model for Conceptual Understanding Formation proposed in this study represents conceptual development as a recursive process of construction, examination, revision, application, and re-engagement. The model explains how students may revisit and reorganize their understanding when confronted with new information, alternative explanations, uncertainty, or contextual demands. It therefore positions conceptual understanding as an ongoing process rather than a fixed outcome of instruction. The principal contribution of the study is an empirically grounded account of how the dimensions of deep learning relate to the pedagogical processes involved in conceptual understanding formation. The model is explanatory rather than causal and is not intended to provide statistical generalization beyond the case examined. Instead, it offers a process-oriented framework for understanding how deep learning may be enacted through interconnected pedagogical

processes in elementary IPAS learning. The findings suggest that deep learning is most meaningful when its pedagogical dimensions are translated into coherent classroom processes that enable students to engage with ideas, examine reasoning, reconsider emerging understandings, and apply knowledge in relevant contexts. This perspective shifts attention from the use of individual instructional techniques toward the functional relationships among the conditions and processes that support conceptual understanding.

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