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EXPLORING SYSTEMIC MISALIGNMENT IN ELEMENTARY SCIENCE LEARNING: IMPLICATIONS FOR PEDAGOGICAL DEEP LEARNING-BASED MICRO CURRICULUM DESIGN

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ABSTRACT

Elementary science education research, as the basis for developing a Pedagogical Deep Learning-based micro curriculum. The study used a qualitative descriptive needs assessment design to investigate the alignment among curriculum intentions, classroom practice, and assessment processes in the implementation of the Merdeka Curriculum. In this study, data were collected through semi-structured interviews with teachers and school principals, classroom observations, and document analysis of lesson plans, curriculum materials, and government-authorized science textbooks from multiple elementary schools in West Java, Indonesia. Data was interpreted using thematic analysis. The results revealed three interconnected learning gaps: Curriculum, Pedagogy, and Assessment. The curriculum gap highlighted the tensions between the inquiry-focused aspirations of policy and the procedural classroom enactment. This difference in pedagogical experience showed that teachers continued to teach science using a primarily teacher-centered approach, limiting students' opportunities for inquiry, reflection, and deeper conceptual understanding. The assessment gap reflects an outdated practice of primarily using recall-based and summative evaluation methods, which stifle creativity and deeper learning. All together, these results point to continuing patterns of science teaching that emphasize coverage over engagement and inquiry. To conclude, this study highlights the need for a Pedagogical Deep Learning-based microcurriculum that supports the development of elementary teachers' agency, is inquiry-driven, and incorporates authentic assessment practices to promote depth and meaning in science learning experiences.

KEYWORDS: Elementary Science Pedagogy, Pedagogy of Deep Learning, Micro Curriculum, Inquiry-Based Learning, Thematic Analysis.

1 INTRODUCTION

In the last several decades, science education in elementary schools has undergone extensive reforms, with an increased emphasis on inquiry-based learning, scientific literacy, creativity, and student-centered pedagogy. Modern science education seeks to do more than rote learning, moving toward experiences where students can engage with a phenomenon and build conceptual understanding (OECD, 2019). In the twenty-first century, inquiry-based science learning is considered vital for developing students' problem-solving skills and higher-order thinking abilities (Hattie, 2012). Similarly, Darling-Hammond et al. (2020) believe that science instruction should not be passive learning in which content is delivered and absorbed; rather, it should actively engage students in exploration, reflection, and collaborative knowledge construction. Despite these policy objectives, elementary science classrooms in many systems continue to rely heavily on procedural instruction, textbook dependence, and the transmission of factual knowledge. As a result, student learning in science focuses on task completion or memorization rather than on the development of deeper scientific understanding and reasoning.

This challenge is particularly evident in curriculum reform contexts, where inquiry-oriented policies often fail to translate into classroom practice. The Merdeka Curriculum implementation in elementary education is a national effort in Indonesia to promote competency-based, creative, contextual, and student-centred learning. Introduction Within elementary science learning, exploration, problem-solving, and inquiry were found to be central to meaningful &mutual learning experiences within the curriculum. However, previous research shows that these curriculum principles are still implemented inconsistently across schools and classrooms (Ananda et al., 2023). According to Suryadi and Rahmawati (2022), teachers often struggle to align curriculum demands with pedagogical approaches that promote conceptual understanding and involve students in a mindful learning experience. Teacher-centered approaches and procedural classroom routines still characterize science instruction. This leads to a permanent rift between what the curriculum is supposed to be, as stated in policy texts, and what it is enacted during actual classroom practice. It also illustrates a more systemic problem of coherence in curriculum reform. For curricular goals to be realized, curriculum implementation must ensure coherence among the elements of a curriculum so that instructional processes, learning materials, and assessment practices support academic achievement. Yet in classrooms, the reality of classroom life often points to a disconnect between curriculum expectations and the ways instruction is actually framed (Priestley et al., 2021). Curriculum reform often fails because teachers are not regarded as pedagogical decision-makers; they are merely positioned as implementers. Fullan (2019) points out that hopes for substantial changes in classroom instruction are dashed when instructional cultures remain ones of compliance and coverage. Many elementary science classrooms still engage in learning activities centered on worksheets, textbook sequences, and the reproduction of factual knowledge. Approaches that may limit students' critical engagement with scientific practices, their ability to ask important questions, and their development of higher-order thinking skills.

This puts the issue of learning depth in the center when we think about how much current science instruction can do. Deep learning is not simply about acquiring content; it involves students in the process of knowledge construction through meaningful inquiry and reflection while engaging cognitive, emotional, and social capacities (Fullan et al., 2019). Deep learning refers to the process by which students develop genuine understanding through active participation, intellectual curiosity, and reflective engagement with ideas (Mehta & Fine, 2019). In addition, Biggs and Tang (2011) state that we should help students connect new knowledge with prior understanding in meaningful learning, as rote learning through memorization of isolated facts would not encourage active knowledge. To that end, science learning should promote real-world problem-solving and transfer across multiple contexts while teaching advanced metacognitive awareness. But those practice distributions driven by tasks such as getting through procedural material and covering prescribed content often miss opportunities for engagement of this sort. It emphasizes the necessity of reframing instruction from a non-participatory, strongly transmissive model to models that emphasize meaningful participation, reflective inquiry, and conceptual understanding.

Pedagogical Deep Learning (PDL) appears to be an attractive framework addressing this issue. PDL describes learning as meaningful, mindful inquiry, and joyful engagement in authentic contexts (Fullan et al., 2019). According to Quinn et al. (2020), deep learning pedagogies encourage students to be actively engaged in collaborative problem-solving and inquiry processes that facilitate conceptual

understanding. Mehta and Fine (2019) go on to elaborate that deep learning environments allow students to own their learning as they develop intellectual authenticity rather than merely completing procedural tasks. PDL is about positioning rather than as passive receivers of knowledge it is a form of active learning, whereby students explore things with others, reflect critically on how and why they learn things in context. Although gaining increased attention in the education literature, very few research studies have explored how PDL principles are realised within classroom implementation of elementary science curriculum, especially as it relates to curriculum reform efforts in Indonesia.

Instructional effectiveness, learning outcomes, media development or teaching strategies dominate existing studies on Elementary science education in Indonesia. Science learning research generally highlights the use of learning models, educational technology, or classroom interventions to improve achievement. But few studies are examining teachers' concurrent instructional competencies and students' conceptual understanding in elementary science classrooms (Rahman et al., 2021). Yet, few studies engage with systemic misalignments among curriculum policy, classroom pedagogy, and assessment practices through the lens of Pedagogical Deep Learning. In fact, there has been little attention to teachers†own interpretation and negotiation of inquiry as they respond to well-entrenched classroom realities that include the [limited time], standardized [learning] materials, and assessment pressures. Gaining insight into these tensions is important for explaining why reform-oriented curricula intended to promote inquiry and creativity tend to manifest in proceduralized, teacher-centered ways of learning.

Some of these challenges can be addressed by innovating the curriculum for better policy design, classroom design, and pedagogical practice. Microcurriculum is viewed as a place-specific and flexible mainstay of the curriculum: Johnson (1975) seeks to bridge the more global objectives of the curriculum with context-specific practices implemented in schools. Likewise, Saylor and Alexander (1981) claim that curriculum design flexibility allows teachers to adapt instructional experiences to learners' needs and sociocultural backgrounds. Priestley and Philippou (2019) go further, arguing that curriculum enactment is always contextualised through teacher agency. Teachers may incorporate these types of science learning experiences through a microcurriculum approach, with the intent to provide opportunities for inquiry, reflection, and conceptual understanding in pedagogical practice.

Nevertheless, designing such a curriculum necessitates systematic knowledge of the science learning opportunities and contextual limitations in elementary science classrooms. It is therefore important to investigate these learning gaps, as this helps us to understand how curriculum reform is enacted in everyday classroom practice and informs the design of context-sensitive pedagogical models. According to Richey and Klein (2007), the first stage of Design and Development Research is to determine contextual problems and instructional requirements before designing educational innovations. Similarly, Dick et al. (2015) highlight the importance of needs analysis for identifying pedagogical difficulties and aligning curriculum design with functional learning environments. In this situation, exploration of the relationship among curriculum policy, instructional practice, and their interpretation, including assessment processes, may offer vital clues regarding the construction of a deep-learning-based microcurriculum. The present study seeks to identify what has been learned and what has not in elementary science, and how the curriculum, pedagogy, and assessment practices function, in line with the principles of Pedagogical Deep Learning.

This research explores the implementation of science curriculum policies in elementary classrooms based on the instructional practices and assessments teachers use. It also seeks to compare and contrast the intended and implemented curriculum in elementary science education with their assessment. The purpose of this research is to identify these gaps, thereby laying the foundation for a PDL-based microcurriculum that encourages deep learning through more meaningful, contextualized, and transformative science education experiences for elementary students.

2 RESEARCH METHOD

In a qualitative needs assessment study, we explored learning gaps in elementary science education as a preliminary step towards a microcurriculum based on PDL. In a particular learning context, needs assessment examines the gap between how things should be in relation to educational objectives and approaches and how they actually are (i.e., instructional practices) (Witkin & Altschuld, 1995). In line with curricular development, needs assessment enables the researcher to identify pedagogical challenges, contextual constraints, and instructional conditions that may interfere with achieving

intended learning outcomes (Kaufman & English, 1979).

The qualitative approach was selected because this study sought to gain insight into the enactment, interpretation, and experience of science learning within a typical classroom context. Instead of measuring literacy and science learning outcomes, we examined the kinds of classroom practices, teacher beliefs, and enactment processes that reproduced inquiry-oriented, deep-learning-based science teaching methodologies. According to Creswell and Poth (2018), qualitative research is well-suited to exploring complex educational phenomena in natural contexts, particularly when the focus is on understanding participants' experiences, interpretations, or meanings of their practices. This study explored ways of teaching and learning observed, experienced, and recorded in selected primary schools, with the concept of PDL (notably meaningful learning, reflective inquiry, and active student participation) in mind, focusing on elementary school science. The research included classroom observation, interviews, and document analysis to identify the disconnections between curriculum intentions (what was intended) and school realities (science teaching practices in relation to science assessment). Thus, the results of this needs assessment sought to empirically inform the design of a microcurriculum that scaffolds conceptual change science education in the elementary-grade context.

The study was conducted at five elementary schools in West Java, Indonesia, that had adopted the Merdeka Curriculum, a competency-based national curriculum emphasizing inquiry, student-centered learning, and conceptual understanding. Purpose: The data were collected from public, Islamic, and semi-private elementary schools to examine differences in science learning across institutional contexts, including five Grade 5 classroom teachers and three voluntarily participating school principals. Teachers in Grade 5 were selected because it is a level at which science instruction typically requires students to engage with increasingly complex concepts, inquiry activities, and problem-solving tasks based on the curriculum's expectations for literacy proficiency. Also housed within the dataset were school principals whose broader lenses on curriculum implementation, instructional policies, and institutional influences may also shed light on science learning.

Participants were selected purposefully based on their direct engagement in delivering elementary science education through the Merdeka Curriculum framework. Purposive sampling facilitates the identification of information-rich cases, those that will shed the most light on the phenomenon, and thus is an important element of qualitative research design. Within this study, participants were deliberately sampled from a range of school contexts to investigate the interpretation and implementation of science curriculum policies in different classroom and institutional environments.

Data were collected through three complementary techniques: classroom observations, semi-structured interviews, and document analysis. The use of multiple data sources enabled methodological triangulation and supported a more comprehensive understanding of how elementary science learning was enacted within classroom practice (Creswell & Poth, 2018). These methods were selected to examine the alignment among curriculum expectations, instructional practices, and assessment processes related to PDL principles.

Table 1: Data Collection Techniques and Research Focus.

Data Source	Purpose	Focus Area
Classroom Observation	To capture real classroom interactions and identify discrepancies between planned and enacted science learning.	Instructional strategies, student engagement, and inquiry-based practices.
Semi-Structured Interviews	To explore teachers' perceptions, challenges, and needs in facilitating creative and meaningful science learning.	Understanding of deep learning principles, curriculum interpretation, and teaching constraints.
Document Analysis (Lesson Plans, Curriculum Guides, Learning Modules)	To examine the intended curriculum and its alignment with higher-order thinking and creativity outcomes.	Integration of learning objectives, materials, and assessments.

Classroom observations were conducted during elementary science learning activities to capture how instructional practices were implemented in authentic classroom contexts. Observations focused on teacher-student interactions, inquiry-based learning processes, student engagement, and the extent to which classroom activities reflected principles of meaningful and reflective learning. Field notes were recorded throughout the observation process to document instructional patterns and contextual classroom dynamics. Semi-structured interviews were conducted face-to-face

with participating teachers and school principals. The interviews lasted approximately 45–60 minutes and were audio-recorded with participants' consent. This interview format allowed participants to describe their experiences, perceptions, and challenges related to the implementation of science learning while also enabling the researcher to probe emerging issues during the conversation (Merriam & Tisdell, 2016). Document analysis was conducted on lesson plans, curriculum guides, teaching modules, and assessment documents used in elementary science learning. The analysis focused on identifying how curriculum objectives, inquiry activities, learning materials, and assessment strategies were represented within instructional documents. These documents also served as contextual data to support triangulation between observed classroom practices and participants' reported experiences.

The study used a qualitative descriptive needs assessment design to explore learning gaps in elementary science education during the implementation of the Merdeka Curriculum. The research began with the selection of five elementary schools in West Java, Indonesia, representing diverse educational contexts, including public, Islamic, and semi-private schools. Participants were purposively selected for their direct involvement in the implementation of science learning and consisted of five Grade 5 teachers and three school principals.

Data were collected in three stages: classroom observations, semi-structured interviews, and document analysis. Classroom observations examined the enactment of inquiry-based science learning, focusing on instructional strategies, teacher–student interactions, and student engagement. Semi-structured interviews with teachers and principals explored their experiences and challenges related to curriculum implementation and assessment practices. In addition, lesson plans, curriculum documents, textbooks, and assessment materials were analyzed to examine alignment between curriculum goals, instruction, and assessment. All interviews were transcribed verbatim and analyzed together with observation notes and documents using Braun and Clarke's (2006) thematic analysis framework. The analysis identified three major themes: curriculum gap, pedagogical gap, and assessment gap. To ensure trustworthiness, the study applied data triangulation, member checking, peer debriefing, and audit trail documentation. Ethical considerations included informed consent, confidentiality, and the use of pseudonyms.

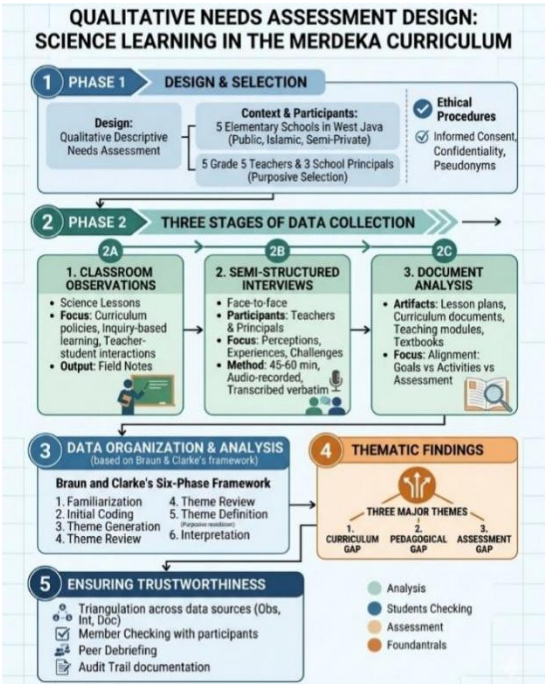

Figure 1: Mediation Model: Digital Literacy as Partial Mediator between Platform Engagement and Technology Adoption.

Qualitative data from semi-structured interviews, classroom observations, and document analysis were analyzed thematically using the six-phase framework defined by Braun and Clarke (2006). Thematic analysis is used due to our knowledge of its systematic yet flexible approach to identifying, organizing, analyzing, and interpreting patterns or themes within qualitative data. This method was considered appropriate for identifying learning gaps in elementary science education and for examining how curriculum, pedagogy, and assessment practices are enacted in the classroom.

The analysis began with the familiarisation stage, where all the interview transcripts, field notes, and curriculum documents were read multiple times to gain a thorough understanding of the data. The interview recordings were transcribed verbatim, and preliminary memos were written to summarize initial impressions, recurring themes, and emerging trends about how participants might practice learning science. Braun and Clarke (2006) highlight that, to put analytic sensitivity into play across the data, researchers must repeatedly engage with the data to understand the intricacies of qualitative material.

After data familiarization, initial inductive coding was conducted to identify significant patterns related to teaching practices, inquiry-based learning, curriculum interpretation, classroom interaction, and assessment. This approach allowed themes to emerge

directly from participants' experiences and classroom contexts rather than from predetermined categories. Next, looked for what those initial codes had in common and the relationships among them to develop larger patterns or themes. Preliminary thematic categories indicating dimensions of recurrent learning gaps across the data were created by grouping related codes. 3 big themes surfaced; curricular gaps, pedagogical gaps, and assessment gaps. The themes emphasized the mismatch between curricular goals and their implementation in practice. After that, the themes were reviewed and revised repeatedly to establish conceptual coherence, internal homogeneity within each theme, and distinct categories (Braun & Clarke, 2012).

Data were interpreted in light of PDL's themes and theoretical concepts. The researcher explored how the themes identified aligned with or contradicted the core dimensions of PDL, including meaningful learning, reflective inquiry, and active engagement in science learning processes. This interpretative phase shifted the analysis beyond describing instructional practice to exploring how instruction supported or constrained opportunities for deep conceptual learning and inquiry. According to Braun and Clarke (2012), thematic interpretation combines empirical patterns with conceptual and theoretical frameworks to generate substantive analytic analyses. Interview data, classroom observations, and curriculum documents were continuously compared to identify alignments and discrepancies among curriculum expectations, instructional practices, and assessment approaches. The analysis revealed recurring tensions between inquiry-oriented curriculum goals and procedural classroom routines, reflecting broader learning barriers in elementary science education.

Lastly, the themes were synthesized into an integrated analytical account that explains the findings of the described learning gaps. While curriculum documents promoted inquiry-based learning, creativity, and conceptual understanding, the thematic synthesis showed that classroom practices leaned more towards procedural tasks, textbook completion, and rote memorization. This pattern highlights disconnects between the intended, implemented, and achieved curricula; in other words, it reflects a problem of coherence. Likewise, Fullan et al. (2019) argue that without pedagogic practices that the reform aims to comprise, and learning processes of deep understanding and reflexivity over compliance with content coverage, most reforms do not bring about meaningful transformation in classrooms.

Figure 2: Diagram Flow Data Analysis Procedure.

3 RESULTS AND DISCUSSION

This section reports findings from the study using data collected from semi-structured interviews with teachers and school principals, classroom observations, and document analysis of lesson plans, curriculum documents, and government-issued science textbooks. Each excerpt is coded by source to improve analytical transparency and enable triangulation across data sources. Interview data were labeled as INT (Interview), classroom observation data were labeled as OBS (Observation), and document analysis was labeled as DOC (Document). Participant identifiers for each participant subcategory, such as Teacher 1 (T1), Teacher 2 (T2), and Principal 1 (P1). Codes such as (INT-T2) indicate interview data collected from Teacher 2; (OBS-Class A) refers to observational data collected during a class session; and (DOC-LP1) indicates that a lesson plan document was examined in the study. The qualitative findings are consistent, traceable, and triangulated using this coding system. The data were clustered into three high-level themes. First, the Curriculum Gap referred to the inconsistencies between what is stated in the curriculum policy and what is implemented in classroom practice. Second, the Pedagogical gap highlighted the discrepancy between the principles of PDL and the actual instructional practices observed during the learning process. Third, the

Assessment Gap described the misalignment between assessment policies and the authentic assessment of student learning outcomes.

For clarity, transparency, and analytical depth, the key findings are synthesized in three analytical tables (Tables 2–4), which integrate evidence from classroom observations, interviews, and document analysis. These tables visually present the recurring gaps identified across the data sources and highlight patterns of alignment and misalignment among curriculum expectations, instructional practices, and assessment approaches. The tabulated findings are further supported by interpretative discussions that situate the empirical results within the theoretical perspectives of Pedagogical Deep Learning (Fullan et al., 2019), curriculum coherence, and authentic assessment (Black & Wiliam, 2009).

Table 2: Data Coding.

Data Excerpt	Source Code	Initial Code	Subtheme	Major Theme
"Students mostly follow instructions from the textbook and rarely ask questions during science lessons."	(INT–T2)	Textbook dependency	Limited inquiry participation	Pedagogical Gap
"Science activities are often focused on completing worksheets because of limited classroom time."	(INT–T4)	Worksheet-oriented learning	Procedural instructions	Pedagogical Gap
During the lesson, students waited for the teacher's directions before starting each activity and showed limited independent exploration.	(OBS–Class A)	Teacher-directed activity	Passive learning behavior	Pedagogical Gap
"The curriculum requires inquiry learning, but assessment still focuses on written tests."	(INT–P1)	Assessment mismatch	Misaligned assessment practices	Assessment Gap
Most assessment tasks in the lesson plan emphasize factual recall and short-answer responses rather than inquiry or reflection activities.	(DOC–LP1)	Recall-based assessment	Limited higher-order assessment	Assessment Gap
"Teachers understand the curriculum goals, but they struggle to apply them consistently in classroom practice."	(INT–T1)	Difficulty implementing the curriculum	Curriculum enactment challenge	Curriculum Gap
The lesson plan stated inquiry-based objectives; however, classroom activities were dominated by lecturing and note-taking.	(OBS–Class B)	Policy-practice inconsistency	Intended vs implemented curriculum	Curriculum Gap
Government-issued science modules encourage creativity and problem-solving, but classroom implementation remains procedural.	(DOC–MOD2)	Inconsistent curriculum translation	Surface-level implementation	Curriculum Gap
Students were actively engaged only during hands-on experiments, and reflective discussion was minimal.	(OBS–Class C)	Limited reflective learning	Weak conceptual engagement	Pedagogical Gap
"We often prioritize finishing the material because there is limited time to explore students' ideas deeply."	(INT–T3)	Content coverage pressure	Limited deep learning opportunities	Pedagogical Gap

Curriculum Gap: Intent vs Implemented Curriculum

The predicate is revealed by analyzing curriculum-related data to determine the extent of the discrepancy between the intended Achievement Learning (CP) Elementary School Science curriculum and the implemented curriculum in classrooms. The Curriculum Principle (CP) states that elementary science education should promote inquiry, problem-solving, and creative reasoning, tied to the context and nature of scientific concepts in real life. Likewise, the Merdeka Curriculum framework emphasizes the underpinning of student agency and real exploration. However, both interviews and classroom observations show they are still far from being achieved in day-to-day teaching.

Table 3: Comparison between Intended and Implemented Curriculum in Elementary Science.

Curriculum Dimension	Intended Curriculum (Policy and Documents)	Implemented Curriculum (Observed Practice & Teacher Interviews)	Identified Gap
Learning Objectives	The *Capaian Pembelajaran (CP) IPAS SD* emphasizes inquiry, problem-solving, and creative reasoning through contextual science learning.	Teachers focus on completing the content listed in government modules, prioritizing factual recall and task completion.	Objectives promoting inquiry and creativity are reduced to procedural, content-based goals.
Learning Approach	Curriculum documents encourage *student-centered*, inquiry-based, and project-oriented learning.	Lessons follow the sequence from textbooks and worksheets with	Misalignment between policy expectations for inquiry-based

Curriculum Dimension	Intended Curriculum (Policy and Documents)	Implemented Curriculum (Observed Practice & Teacher Interviews)	Identified Gap
		limited inquiry activities. Most lessons are teacher-directed.	learning and the classroom's teacher-centered practice.
Learning Materials	Textbooks and modules aim to connect science with everyday contexts and real-world examples.	Teachers rely strictly on textbook examples, rarely adapting or expanding them to local contexts.	Curriculum interpreted as a fixed template, not a flexible guide.
Teacher Role	Teachers are expected to act as facilitators who guide students to construct meaning through investigation.	Teachers act mainly as instructors, transmitting information and checking task completion.	Limited teacher agency and autonomy in interpreting curriculum content.
Student Role	Students should explore, question, and construct understanding through active participation.	Students listen, copy notes, and respond to direct questions; limited exploration or inquiry.	Passive student involvement inhibits the realization of "student agency."
Integration with Local Context	Curriculum encourages contextual adaptation and integration with local phenomena.	Teachers rarely link lessons to students' local environment due to rigid adherence to national modules.	Loss of contextual relevance reduces meaningful engagement.

The intended curriculum supports inquiry- and context-based science learning, as summarized in Table 1, but the implemented curriculum remains procedural and teacher-centered. This gap reflects weak curriculum coherence, a disconnect between policy and practice. A teacher from the survey commented that lesson delivery often follows a "step-by-step" format with government-controlled modules.

We usually work on the provided module, since students must complete every step by completing all tasks, even if they didn't really get the concept. (Interview, a participating teacher) It means evidence that we are doing the things to teach -- covering and going deep, etc., another teacher said. Time is limited, and we have numerous materials to cover. It is hard to build exploratory work in such a tight timeframe." (Interview, a participating teacher)

Observation data support these perspectives. In almost all classrooms, you see strict adherence to textbook sequences and activity sheets, with the teacher largely serving as a knowledge transmitter. Lessons were primarily procedural—presenting definitions and making brief demonstrations, but closing with summaries that prevented further investigation. Student engagement was largely passive, with few students observed questioning or formulating hypotheses about the phenomena presented. This tension is exemplified by an observed class on "The States of Matter." The science teacher showed melting and evaporation using ice and a kettle, but the follow-up discussion stayed at the level of factual recall. Students echoed the terms solid, liquid, and gas, but when asked how/why melting happens at all, they went mostly silent or sputtered out partial answers. This is an example of what Biggs and Tang (2011) refer to as "surface learning," in which knowledge is fragmented and not linked to conceptual understanding.

This gap in the curriculum is further solidified through document analysis. Although the Lesson Plan specifies goals, such as developing students' ability to explain physical phenomena based on observations and reasoning, the planned learning activities emphasize "completing tasks" rather than "constructing understanding." There was partial alignment between objectives, activities, and assessment criteria. While inquiry and creativity were mentioned as objectives in the materials, indicators or tasks favored correct answers over exploration or reflection.

Textbooks in elementary school Natural and Social Sciences also increase this tension, as they are government-issued. While the preface champions scientific literacy and learning in context, tasks and questions woven into chapters are largely low-order and factual (e.g., "List three examples of living things that can move"). Litigation, guesser (and low-bias unless followed by an information-collection task), and linear explanation. All three activities offer little incentive to predict, explain, or reason based on evidence. As a result, teachers understand the curriculum as a series of content units rather than an integrative learning process.

Idea of the "curriculum spider web" where all four components interact, and consequently, where coherence across objectives, content, pedagogy, and assessment determines curricular effectiveness. That coherence does not appear to be present in the current study. We argued that teachers saw the curriculum as externally imposed rather than as a flexible framework to be exploited locally. As one school principal commented, "The data is already organized into a government module, and we use it." If we change too much, this may not align with the assessment format." (Interview, a school principal) This and other utterances suggest that the teachers had little agency to interpret or contextualize

curriculum materials, a dilemma described by Fullan et al. (2019) in settings for educational reform as a dilemma of teachers as implementers rather than co-designers. Lacking autonomy contributes to a mechanistic approach to implementing curriculum elements, diminishing real engagement (first dimension of PDL).

Thus, in practice, policy ideals (intended curriculum) and classroom realities (implemented curriculum) are disconnected by structural constraints (e.g., time, assessment systems) and cultural habits (traditions and orientations toward teacher-centered ways of being). The result is that what you are developing is a procedural enactment, rather than a conceptual one of science learning. This curriculum gap can be addressed by establishing teachers as reflective designers who will adapt learning goals into local, inquiry-based practices.

As Fullan and Quinn (2020) argued, deep learning reform begins with capacity building rather than compliance. In the context of Indonesian elementary science education, this requires shifting curriculum policy from delivery to design, and from standardization to contextualization, so that learning becomes genuinely meaningful, mindful, and enjoyable.

Pedagogical Gap: Instructional Practices and Lack of Flexible Learning

The second theme, the pedagogical gap, captures the disconnect between what teachers intended in terms of instruction and how that intention plays out in classroom learning experiences. While the Merdeka Curriculum promotes inquiry-based and student-centered learning, the data reveal that much science instruction is teacher-directed, focusing on knowledge transmission rather than construction.

Data from observations indicate that teachers often use expository teaching, featuring question-and-answer sequences within short demonstrations. Classes start with the teacher explaining the topic from a textbook, followed by guided questions like "What do you see?" or "What is it that roots do?" The students respond in chorus, reciting everything they have memorized. There were limited opportunities for students to design experiments or generate hypotheses. Many of the classrooms visited were characterized by an imbalance in which most of the learning time was spent on teacher talk, while exploration or reflection accounted for only a small fraction of the available time. To demonstrate the disconnect between PDL's intended goals and actual classroom instructional practices, Table 4 summarizes key differences identified from the data.

Table 4: Comparison between Deep Learning Principles and Observed Teaching Practices.

Pedagogical Dimension	Deep Learning Principles (PDL Framework)	Observed and Reported Teaching Practices	Identified Gap
Learning Design	Learning experiences are designed to promote exploration, collaboration, and reflection (Fullan et al., 2019).	Lessons are teacher-led with limited opportunities for exploration or peer dialogue. Students often follow instructions passively.	Learning remains activity-based but lacks conceptual depth and reflection.
Student Engagement	Students are active learners who question, investigate, and construct meaning.	Engagement occurs mostly through repetition or short Q&A sessions; few students ask questions or initiate ideas.	Surface engagement dominates; critical questioning and ownership of learning are limited.
Inquiry Process	Teachers guide students to investigate and construct scientific understanding through evidence-based reasoning.	Teachers demonstrate phenomena but rarely invite students to hypothesize or interpret results.	Inquiry is procedural (observation only) rather than conceptual (reasoning-based).
Learning Environment	Classrooms should encourage curiosity, creativity, and collaborative problem-solving.	Teachers express concern about managing "noisy" classes during group work, leading them to avoid open-ended activities.	Teacher confidence and classroom management issues limit collaborative exploration.
Use of Learning Media	Diverse media and local contexts are used to make learning meaningful and connected to students' lives.	Teaching relies on government textbooks, with minimal adaptation to local contexts or use of real materials.	Limited contextualization reduces meaningful and joyful engagement.
Teacher's Role	Teachers act as designers and facilitators of learning, guiding students toward deep understanding.	Teachers function as knowledge transmitters, prioritizing content coverage over inquiry facilitation.	The teacher's role remains traditional, inhibiting *mindful inquiry* and learner autonomy.

While PDL principles champion exploration, collaboration, and conceptual reasoning, most of the classrooms we observed were still using teacher-centered procedural practices. This finding supports the 'implementation gap' (Hattie, 2012), whereby teachers recognize innovative pedagogies but struggle to implement them in practice. Consequently, important affordances for authentic engagement, reflective questioning, and playful learning that underpin PDL remain rare in current approaches to teaching science.

The following field note describes a typical scenario: While teaching a lesson on energy transfer, the teacher brought out a small model of an automobile. Students who saw the phenomenon but were prevented from showing motion and were not asked to explain why or to associate it with energy conversion (Observation, a participating classroom). Interviews with teachers confirmed this pattern, noting that such inquiry-based learning is ideal but difficult in practice due to contextual constraints. One teacher explained: "Our challenge is we want students to experiment more, but the supplies and tools are limited. If something goes wrong, it takes too long (Interview, a participating teacher). Another teacher raised classroom management challenges: This is why I have done the structured sentence starter (which you will find below in the few areas they are). The class is loud if students work in groups. Asking them to stay on the topic is next to impossible (Interview, a participating teacher).

Such accounts are indicative of what Hattie (2012) describes as the 'implementation gap' between pedagogical ideals and actual practices. Teachers like inquiry and participation, but are forced to rely on more didactic approaches that seem easier to implement in large classes and with limited time. At the same time, the analysis of the lesson plans supports this observation. Lesson plans often describe learning objectives in terms of inquiry and reasoning, but the procedures they outline focus on teacher explanation and students filling out worksheets. The talk you will hear will include many common phrases, such as students watch, which is associated with tasks that lack scaffolding for hypothesis testing, reflective use, and in-depth analysis. These types of activities. Like project-based learning, which is mentioned but not a focus of the standards, these are typically short-term tasks (e.g., diagram labeling; summaries) rather than authentic inquiries. This is an exemplar of a partial grasp of deep learning pedagogy. According to Fullan et al. (2019), deep learning involves engaged students who are both cognitively and emotionally present as a result of purposeful inquiries. And the absence of such questioning in the lessons we observe tends to suggest that our teachers confuse activity with understanding, providing none of those frictional links in students' heads.

I am happy to say that there were a few joyful learning moments that stood out. For instance, in an exploration of the forces magnets exert, kids had a blast trying out different kinds of magnets while laughing and talking about what they noticed. Almost instantly, though, the teacher redirected students to finish a worksheet: Reflection and peer exchange would have to wait. In this episode, we see how engagement can become a pleasurable, shallow affair without growing into deeper understanding.

Thus, the good old pedagogical gap here is not simply a lack of pedagogy but a lack of the pedagogue's mindset and confidence. In contrast, teachers see inquiry as risky and time-consuming when they prefer procedural efficiency. What is needed are professional learning opportunities that go beyond clinical approaches to include developing reflective capacity and adaptive expertise (Timperley, 2011). PDL will only take root in science classrooms if teachers see themselves as learning experience designers.

Assessment Gap: Lack of Realistic and Imaginative Evaluation

Another theme, the assessment gap, underscores disconnections between the curriculum's commitment to real-world, competency-aligned assessment and actual evaluation practice. Interviews and document analysis show a high number of written tests, combined with short-answer quizzes, serving as the predominant forms of assessment. One teacher acknowledged: "The test is used more because it's the simplest to document pupils' scores." And even though estimates are a long way from the established research standard (as you can well imagine, it is difficult to measure creativity or reasoning)" (Interview, a participating teacher). Another teacher noted: "We have an assessment rubric in the lesson plans, but we seldom use it completely, as we have to provide numeric scores for reports" (Interview, a participating teacher). Observation data corroborates these statements. Assessment was mainly based on how students completed worksheets or end-of-topic quizzes. Feedback was brief and summative; responses were correct or incorrect, with little attention to students' thinking processes. In one session, we observed that she went through the answers on the board for a multiple-choice question without addressing any underlying misconceptions.

Despite the emphasis on inquiry-based, process-oriented evaluation in curriculum documents, classroom assessment methods remain traditional and content-based. This contrasts with a normative culture of summative assessments, where tests are used to report performance on the subject rather than to improve learning in elementary science classrooms. Teachers placed a high value on written tests and worksheet completion, while formative feedback and reflective discussions were rarely used

in instruction. A comparison of the major findings from document analysis, teacher interviews, and classroom observations is presented in Table 5, which highlights the discrepancy between intended assessment principles and practice.

Table 5: Comparison between Current Assessment Practices and Authentic Assessment Principles in Pedagogical Deep Learning.

Assessment Dimension	Authentic Assessment Principles (PDL Framework & Curriculum Policy)	Observed and Reported Practices	Identified Gap
Purpose of Assessment	Assessment serves as a learning tool (*assessment for learning*), guiding reflection, feedback, and student self-assessment (Earl, 2013; Fullan et al, 2019).	Teachers use assessment mainly for grading and reporting purposes at the end of units. Reflection or formative feedback is minimal.	Assessment is summative-oriented, with limited feedback loops to support deep learning.
Assessment Method	Multiple assessment forms (project, performance, portfolio, peer evaluation) are used to capture creativity and understanding (Brookhart, 2010).	Written tests and worksheet completion dominate. Rare use of project- or performance-based assessments.	Lack of authentic tasks that evaluate creativity, reasoning, and application of science concepts.
Feedback Process	Continuous feedback between teachers and students is emphasized to promote *mindful learning* and self-improvement.	Feedback is mostly evaluative ("correct/incorrect") rather than dialogic or constructive.	Feedback does not enhance metacognition or self-regulation.
Student Involvement	Students assess their own work through reflection and peer assessment.	Students are passive recipients of grades; self-assessment activities are rarely observed.	Student agency in assessment is not realized.
Alignment with Learning Goals	The assessment aligns with the inquiry-based and creative thinking objectives in the curriculum documents (CP IPAS SD).	Tests focus on factual recall (definitions, labeling, procedures) rather than inquiry or conceptual understanding.	Misalignment between assessment content and curriculum intentions.
Documentation and Reporting	Portfolios and narrative records document progress in learning processes and competencies.	Assessment reports focus on numeric scores with limited qualitative description.	Evaluation lacks holistic evidence of student growth.

Although incremental advances have led to more advanced assessment practices in elementary science, as shown in Table 5, results remain summative and procedural. Many of the characteristics of authentic assessment—such as reflection, self-assessment, and use in inquiry learning—are used very little. The finding supports that of Black and Wiliam (2009) and Gulikers et al. (2005), who detail several teachers struggling to enact formative and authentic assessment within a high-stakes testing culture. This means that the mindful and joyful aspects of learning are still not represented in assessment design, thereby restricting students' deep reflection on their own learning within the PDL framework. Lesson plans and curriculum document analyses indicate additional misalignment. The Learning Outcomes — Elementary Sciences promote assessment as learning through observation, reflection, and self-assessment. However, the assessment sections in the lesson plans reviewed were overpowered by summative tools such as "written tests" and "task completion." Creative performance or reflective discussion was seldom included.

Being assessed this way limits students' chances of engaging in mindful inquiry, the second aspect of PDL, as evaluation focuses on outcomes rather than processes. According to Black and Wiliam (2009) and Brookhart (2010), formative assessment is essential to higher-order thinking and creativity. But in these classrooms, assessment is still a tool of compliance rather than a driver of learning. This is supported by document analysis of the actual textbooks provided to students by the government. Chapter questions at the end of most chapters are all low-level ("Name two Examples of renewable energy," etc.) and involve little justification or free-response-style reasoning. Authentic assessments are rarely found in textbooks, and this tendency shapes how teachers design assessments.

Without models of the creative and reflective tasks we intend for students to do, teachers resort to standardized tests. From the perspective of PDL, this is a shallow form of engagement—in other words, when students are tested for recall rather than reasoning, their intrinsic motivation to learn is diminished. As one school principal observed, Students recall before an examination, then tend to forget quickly. "Time for reflection is not opportune (Interview, a school principal). To address this gap, there is a need to improve teachers' assessment literacy. By making assessment results easily accessible, educators also get the support they need to design authentic assessment strategies, such as inquiry journals, observation checklists, and performance-based rubrics. Moving away from the judgmental use of assessment by integrating it with learning rather than merely appending it, more formative assessment may encourage deeper, more creative understanding (Earl, 2013).

Combined Overview and Theory

Our insights into curriculum, pedagogy, and assessment indicators revealed a systemic misalignment in the implementation of elementary science teaching under the Merdeka Curriculum. The curriculum's policies promote inquiry, creativity, and contextual understanding, but this is mostly reduced to procedural, teacher-directed, and assessment-driven processes in classrooms. Instead of functioning as mutually interacting parts of a unified learning system, the curriculum goals, instructional practices, and assessments seem disjointed—indicating what might be called a pedagogical coherence gap. Such disconformity is available in all data sources on your behalf. Curriculum documents stress inquiry and creative reasoning clearly, but teachers often characterize their experience as being unable to do the work because completing the materials is prioritized. As one teacher explained: We typically stick to the learning path within the module, and each task must be completed even when students do not have a real understanding of the principle (INT–T2).

In this way, the broader purpose of petitions as procedural compliance rather than pedagogical intent is reflected in the curriculum enactment. In fact, classroom observations suggested that students spent most of their time during lessons completing worksheets and answering factual science questions rather than generating explanations or pursuing independent scientific investigations. These results implied that the intended curriculum had been reduced to a series of teaching tasks rather than fostering meaningful learning.

From a curriculum-theoretical perspective, curriculum coherence is the alignment of educational aims/content/pedagogy/assessment. In the current study, this coherence appears to be considerably diminished. Learning objectives promote inquiry and conceptual understanding; instructions and routines emphasize efficiency and coverage; and assessments primarily focus on factual recall. This fragmentation has been addressed as an implementation gap, but should rather be seen as a structural disconnect between policy aspirations and on-the-ground realities.

The results are also consistent with curriculum enactment theory, which emphasizes that curriculum is not merely delivered but enacted and adapted by teachers in the context of institutional and cultural pressures (Priestley et al., 2021). In the research, teachers appeared to position themselves mainly as curriculum deliverers rather than as curriculum makers. One school principal noted, "We have the government module ready-made, and we simply use it." If we change it too much, then it may not be the same format for the assessment (INT–P1). This statement exhibits little teacher agency and indicates that curriculum flexibility—one of the key promises of the Merdeka Curriculum has yet to manifest, in a substantive sense, into pedagogical autonomy. Meaningful curriculum reform is contingent not just on how policy is designed but also on teachers' capacity and ease of use in enacting the curriculum in meaningful ways in local contexts (Priestley & Philippou, 2019).

Within the PDL framework (Fullan et al., 2019), the science learning environment in the present case is dreadfully unbalanced across its three core dimensions: meaningful but not deep enough, mindful but not creative enough, and joyful but not engaging. The overreliance on textbooks and fixed sequence lessons may hinder meaningful engagement. While science topics are designed to tie into students' lived experiences, in practice, only a small handful of the discovery or exploration assignments were contextualized. Students usually solve problems without showing their knowledge of the concepts involved, which is what Biggs and Tang (2011) mean by surface learning.

Second, the inquiry seems stunted in its development due to teacher-centered pedagogy and a lack of confidence in open-ended exploration. In fact, one of the most common concerns teachers raised about inquiry-based activities was that they would be too time-consuming and resource-intensive or difficult to manage. One teacher admitted, "However, parts and tools are restrictive, so we want students to experiment more." If he does something wrong, it is too late (INT–T4). This shows that, even with acknowledgment that inquiry is essential based on research describing its efficacy, practical constraints and pedagogical uncertainty prevent these teachers from implementing it. In their comparison of the domains of cognitive objectives and aspects of deep learning, Mehta and Fine (2019) find that questioning and reasoning, as well as opportunities for reflection, are missing from most classrooms—whether observed or not.

Third, joyful learning was only in fleeting instances and rarely sustained through reflective dialogue or student buy-in. In multiple classroom observations, students were engaged in hands-on experiments, but these short-lived interests usually succumbed to worksheeting or teacher explanation. This indicates that there was emotional involvement, but it did not shade into a deeper conceptual understanding. As far

as PDL is concerned, joy without reflection never comes to a close. The assessment findings further validate this pattern. However, in reality, teachers rely on written tests and task completion to meet policy expectations for authentic and formative evaluation. As one teacher acknowledged: "So, through tests we still deliver our attention because it's the easiest way I know." It is nearly impossible to measure creativity or reasoning." (INT–T3) This illustrates the phenomenon Black and Wiliam (2009) describe: a legacy of summative assessment that served more to hold individuals accountable than to promote learning. These practices limit opportunities for metacognition, self-assessment, and reflection within the PDL framework for student learning, which is necessary for the development of deeper scientific understanding. Overall, we argue that these findings suggest the central problem is less about a lack of innovative teaching strategies per se than, more fundamentally, about pedagogical identity and professional agency. Educators seem trapped between the desire to reform and the ability (rightly or wrongly) to comply. They are designed to enable inquiry but are measured by standardized outputs; urged to differentiate learning but reliant on static instructional modules. This is a contradiction that Fullan et al. (2019) describe as implementation without transformation. This paper argues that meaningful curriculum shuffling through the introduction of new policy documents is inadequate. What is required is to move from the delivery of curriculum, which positions teachers as vessels responsible for transmitting knowledge, to practice-based curriculum design that allows teachers to reflect on the pedagogical decisions necessary to adapt science learning to students' needs in their local contexts. To this end, a Pedagogical Deep Learning-based micro curriculum is proposed as a possible way forward. As these days one needs to provide teachers with flexible, context-sensitive curriculum frameworks that effectively knit together inquiry content and authentic assessment, a microcurriculum may help close the gaps this study has identified.

Additionally, the results align with broader debates about curriculum reform and 21st-century skills in modern education. According to Arifin et al. (2026), the core of the Industry 5.0 curriculum construction era cannot focus solely on content mastery; it should also be skill-oriented, with competent students expected to acquire soft skills such as adaptability, creativity, collaboration, and reflective problem-solving. Their research demonstrates that competency-oriented design is essential when devising curricula that prepare students to act on increasingly complex, innovation-led social change challenges. Likewise, the implementation of STEAM-integrative curriculum contributes positively to students' character maturity, creativity, critical thinking, and skills in the twenty-first century through collaborative and inquiry-based learning experiences (Arifin et al., 2026; Kurniawan et al., 2026). Overall, these findings strengthen the argument of this study that procedural science instruction, inflexible textbook-driven pedagogies, and recall-oriented examination systems have narrowed current students' recognition of the higher-end skills demanded of young global citizens over the past century. Therefore, the gaps found in curriculum implementation, teaching, and assessment are not only weaknesses in classroom instruction but also reflections of broader challenges associated with preparing students to contribute productively to future knowledge-intensive and innovation-driven economies. Hence, we consider that developing a Pedagogical Deep Learning-based microcurriculum is becoming increasingly relevant for generating inquiry, creativity, collaboration, contextual reasoning, and reflection, and for problem-solving through more flexible, meaningful, and student-centered science learning experiences.

In the end, the results show that deep learning cannot shine in an environment governed by procedural compliance. Educational transformation starts when teachers progress from compliance to curiosity—stepping outside of rigid steps to purposefully plan learning experiences that bring knowledge and creativity together (Fullan & Quinn, 2020). Viewed through this lens, the current study establishes the empirical and theoretical basis for the next phase of this Design and Development Research process: co-designing a pedagogical, deep-learning-oriented microcurriculum that articulates how meaningful, mindful, and joyful science learning might be fostered in Indonesian elementary schools.

4 CONCLUSION

This exploratory study identified three interconnected gaps in elementary science education during the early implementation of the Merdeka Curriculum in Indonesia: curriculum, pedagogy, and assessment. Although the curriculum promotes inquiry-based and student-centered learning, classroom practices remain dominated by procedural instruction and recall-oriented assessment, revealing weak alignment between curricular intentions and instructional practice. To address this issue, the study proposes a Pedagogical Deep Learning-based

microcurriculum that integrates inquiry-oriented instruction with authentic assessment to foster meaningful science learning. The findings emphasize the importance of strengthening teacher agency, reflective practice, and assessment literacy. Despite its limited scope in West Java, this study provides a foundation for future research on the implementation and sustainability of deep learning-oriented science education across diverse educational contexts.

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