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Content Analysis of Biology Learning Objectives in Merdeka Curriculum: Detection of Misconceptions and Terminological Interference from Predecessor

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Abstract: Indonesia's shift from Curriculum 2013 to the Merdeka Curriculum has introduced significant challenges in biology education, particularly in formulating competency-based learning objectives. This study analyzes professional misconceptions in learning objectives using qualitative content analysis of eight curriculum documents—lesson plans and teaching modules—focused on "Environmental Change" from three provinces (Aceh, North Sumatra, Bangka Belitung). Contributors included senior teachers, junior teachers, and pre-service teachers under mentor guidance. Using Webb's curriculum alignment methodology and Bloom's revised taxonomy, we identified three misconception categories. Structural misconceptions showed 75% of documents retained outdated behavioral formats misaligned with competency-based paradigm. Semantic misconceptions demonstrated mean cognitive level drop of 2.1 levels from expected C6 to observed C1–C3 objectives. Pragmatic misconceptions revealed 62.5% used low-validity, recall-based assessments. These consistent patterns across regions and teacher experience levels suggest systemic rather than contextual issues. Professional misconceptions mirror student cognition patterns, characterized by structural coherence and resistance to surface-level correction. Addressing these requires explicit conceptual change strategies, not mere technical training. This study offers a research-based framework to inform interventions for effective competency-based biology instruction adoption.

Keywords: Biology education; Cognitive degradation; Competency-based curriculum; Learning objectives; Misconceptions

Introduction

Competency-based biology education represents a fundamental paradigm shift from traditional behavioral objectives toward integrated knowledge, skills, and attitude development within authentic contexts (Anderson & Krathwohl, 2001; González-Salamanca et al., 2020). This transformation requires educators to reconceptualize learning objectives as complex competency integration tools rather than discrete behavioral targets, creating unprecedented implementation challenges that extend beyond technical training to fundamental conceptual restructuring (Felder & Brent, 2016; Tyler, 1949).

Indonesia's Merdeka Curriculum implementation exemplifies these challenges through semantic interference—where familiar terminology persists while underlying meanings undergo radical transformation

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(Fairclough, 2003). The term "learning objectives" continues from Curriculum 2013 to Merdeka contexts, yet requires completely different conceptual frameworks for appropriate implementation. Implementation challenges stemming from implementers' incomplete understanding of curriculum objectives, creating gaps between policy intentions and classroom practice (Ndari et al., 2023).

Chi (2005) ontological categories mismatch theory explains why such implementation challenges persist systematically. When educators encounter new competency-based requirements, they naturally categorize this information using familiar behavioral objective frameworks, creating interpretations that appear logical within existing knowledge structures while systematically distorting reform intentions. This represents professional misconceptions—coherent but incorrect interpretive frameworks that exhibit the same characteristics as student misconceptions: resistance to change, internal consistency, and systematic persistence despite corrective information (Ohlemann et al., 2023; Vosniadou, 2013).

This research addresses three critical gaps in biology education literature. First, while extensive research documents student misconceptions in biology content areas (Fuchs & Arsenault, 2018; Guerra-Reyes et al., 2024), professional misconceptions about curriculum requirements remain unexplored despite evidence that educator interpretive frameworks directly influence instructional quality (Darling-Hammond, 2000). Second, Indonesian research consistently documents Merdeka implementation challenges, including impacts on teacher motivation and performance (Ashari et al., 2025) and curriculum transition difficulties (Hidayat et al., 2025), inconsistent pedagogical approaches (Setyaningsih et al., 2023), and systematic implementation obstacles (Cahyanti et al., 2024; Marthawati & Setyo, 2024) yet underlying causes remain inadequately explained. Third, understanding misconception patterns provides evidence-based foundations for improving professional development approaches (Cuban, 2013; Fullan, 2007).

This study provides the first systematic analysis applying established misconception theory to professional conceptual change in curriculum implementation contexts. The novelty lies in three unprecedented contributions: Theoretical Extension—demonstrating that professional misconceptions exhibit systematic patterns parallel to student misconceptions, extending Chi's ontological theory to educator contexts; Methodological Innovation—developing a three-dimensional analytical framework (structural, semantic, pragmatic) enabling systematic detection of professional misconceptions in curriculum documents; and Empirical Documentation—providing the first quantitative evidence of systematic cognitive degradation patterns in learning objective formulation, revealing measurable gaps between policy intentions and educator implementations.

The findings offer evidence-based foundations for developing intervention strategies that address conceptual restructuring requirements rather than focusing solely on technical training, potentially improving curriculum transition effectiveness in Indonesia and similar contexts globally.

Literature Review

Professional Misconceptions in Educational Change

Misconception research in education has expanded beyond student conceptual understanding to examine professional misconceptions among educators during reform implementation. Chi (2005) research demonstrates that misconceptions arise when new information cannot be properly categorized within existing knowledge structures, creating systematic but incorrect interpretations. Recent research confirms that professional misconceptions exhibit characteristics similar to student misconceptions: coherence, resistance to change, and logical consistency within alternative frameworks (Antonenko & Abramowitz, 2023; Ohlemann et al., 2023).

In curriculum transition contexts, educators may adopt new terminology while maintaining underlying conceptual frameworks from previous curricula, creating semantic compliance without substantive implementation (Little, 1993). This pattern is supported by Vosniadou (2013) framework theory explains how educators create synthetic frameworks combining elements of new policy information with persistent presuppositions from previous experience. This process results in hybrid interpretations that maintain internal coherence while systematically distorting reform intentions, particularly when fundamental philosophical shifts are involved.

Biology Education Misconceptions and Curriculum Implementation

Biology education research documents persistent misconceptions that significantly impact teaching effectiveness and student learning outcomes. Fuchs & Arsenault (2018) analyzed 23 years of assessment data, revealing systematic misconception patterns that resist traditional professional development approaches. Their findings demonstrate that misconceptions in biology education operate at multiple levels, from content-specific concepts to broader pedagogical frameworks.

Research on science education misconceptions has progressed from foundational studies (Driver & Easley, 1978) to sophisticated theoretical frameworks

recognizing misconceptions as complex knowledge structures rather than simple errors (Hammer, 1996). Contemporary systematic reviews confirm that misconceptions are pervasive across natural sciences education and require targeted analytical approaches (Guerra-Reyes et al., 2024). This theoretical evolution provides the foundation for analyzing misconception patterns in biology education.

Assessment Theory and Learning Objectives

Tyler (1949) foundational work in curriculum development established the critical importance of coherent objective formulation as the basis for effective curriculum implementation and assessment design. His principles demonstrate that learning objectives serve as fundamental elements that directly influence instructional design, assessment practices, and student learning outcomes. Anderson & Krathwohl (2001) revision of Bloom's taxonomy provided updated frameworks for understanding cognitive complexity in learning objectives, emphasizing the integration of knowledge types with cognitive processes.

Assessment theory research demonstrates that clarity and appropriateness of learning objectives significantly impact assessment validity and instructional effectiveness. This principle is supported both theoretically by Eisner (2013) and practically by Andrews 2013), emphasizing that learning objectives must provide clear guidance for both instruction and evaluation to support student learning effectively. Shepard (2000) extended this understanding by examining the role of assessment in learning culture, emphasizing how teachers' beliefs about learning and assessment impact instructional coherence. Hattie & Timperley (2007) contributed understanding of feedback effectiveness, showing how unclear learning objectives prevent effective feedback provision and student improvement.

Curriculum Implementation Theory and Professional Development

Educational change theory provides essential frameworks for understanding curriculum implementation challenges. Fullan (2007) work on educational change emphasizes that successful curriculum implementation requires sustained support and conceptual restructuring rather than information transmission approaches. Cuban (2013) research on classroom practice change demonstrates that educators often maintain familiar approaches despite policy requirements, creating implementation scenarios that appear compliant while fundamentally misaligning with reform intentions.

Professional development research by Darling-Hammond (2000) establishes connections between teacher conceptual understanding and implementation quality, demonstrating that experience without adequate theoretical foundation may reinforce incorrect interpretations. This finding supports evidence that experience with previous curricula can impede adaptation to new approaches when fundamental philosophical shifts are involved. Research by Pak et al. (2020) on adaptive challenges in curriculum implementation provides contemporary understanding of how educators navigate complex requirements during reform transitions.

Terminological Interference in Curriculum Implementation

Bourdieu (1991) concept of linguistic habitus explains why professional discourse resists change despite official policy transformation: teachers internalized linguistic structures from previous curricula continue to influence their interpretation of new terminology.

Recent research on Merdeka curriculum implementation reveals significant gaps between policy intentions and classroom practice, with teachers demonstrating limited understanding of key curriculum components (Haq & Wakidi, 2024). Fairclough (2003) analysis of discourse and textual analysis provides theoretical foundations for understanding how semantic lag patterns emerge, where terminology evolves more slowly than conceptual frameworks, creating systematic implementation barriers.

Indonesian Educational Context and Implementation Challenges

Studies document systematic difficulties in maintaining student-centered learning approaches despite policy emphasis on these pedagogical strategies, suggesting fundamental misconceptions about curriculum requirements persist across implementation contexts. Contemporary research demonstrates specific challenges in biology education during Merdeka Curriculum implementation, with Hidayat et al. (2025) finding that despite improved learning media applications, higher-order thinking skills development remains inconsistent.

Research by Ashari et al. (2025) on teacher motivation and performance during curriculum transition indicates that implementation quality varies significantly based on conceptual understanding rather than technical skill acquisition. Setyaningsih et al. (2023) found that while technological integration improves in Merdeka contexts, fundamental pedagogical approaches often maintain traditional patterns inconsistent with competency-based philosophy. Syahrir et al. (2024) documented systematic implementation variations across Indonesian schools,

confirming that Merdeka curriculum challenges stem from conceptual rather than contextual factors.

Regulatory Evolution and Semantic Instability

Indonesia's regulatory evolution of learning objectives demonstrates unprecedented conceptual volatility. From initial general formulation in Ministry of Education Regulation No. 65/2013 (Kementerian Pendidikan dan Kebudayaan Republik Indonesia, 2013), through complete elimination in No. 103/2014 (Kementerian Pendidikan dan Kebudayaan Republik Indonesia, 2014), dramatic reintroduction with ABCD framework in No. 22/2016 (Kementerian Pendidikan dan Kebudayaan Republik Indonesia, 2016), transformation to paragraph form in No. 34/2018 (Kementerian Pendidikan dan Kebudayaan Republik Indonesia, 2018), initial Merdeka Curriculum establishment in BSKAP Decision No. 033/2022 (Kementerian Pendidikan, Kebudayaan, Riset, dan Teknologi Republik Indonesia, 2022), to current refined standards in BSKAP Decision No. 032/2024 ((Kementerian Pendidikan, Kebudayaan, Riset, dan Teknologi Republik Indonesia, 2024), educators have experienced cascading conceptual disruptions that create optimal conditions for misconception formation.

This regulatory timeline created systematic challenges where educators who mastered scientific process indicators (2014), then adapted to rigid ABCD behavioral formatting (2016), subsequently encountered holistic paragraph integration requirements (2018), before facing current competency-based transformation (2024). Research by Gouëdard et al. (2020) on curriculum reform implementation provides international context for understanding how regulatory volatility creates implementation barriers, while contemporary research confirms that terminological persistence continues to create systematic misconceptions despite policy improvements.

Method

Research Design

This study employed systematic qualitative content analysis to identify professional misconception patterns in biology learning objectives during Indonesia's 13-to-Merdeka curriculum transition. Content analysis was selected because it enables comprehensive examination of both manifest and latent content in educational documents while maintaining systematic rigor in pattern identification (Krippendorff, 2019). The analytical framework integrated Chi (2005) ontological misconception theory and Webb (1997) curriculum alignment framework to provide theoretical foundation for deductive coding while allowing inductive pattern emergence.

Methodological Flow Overview

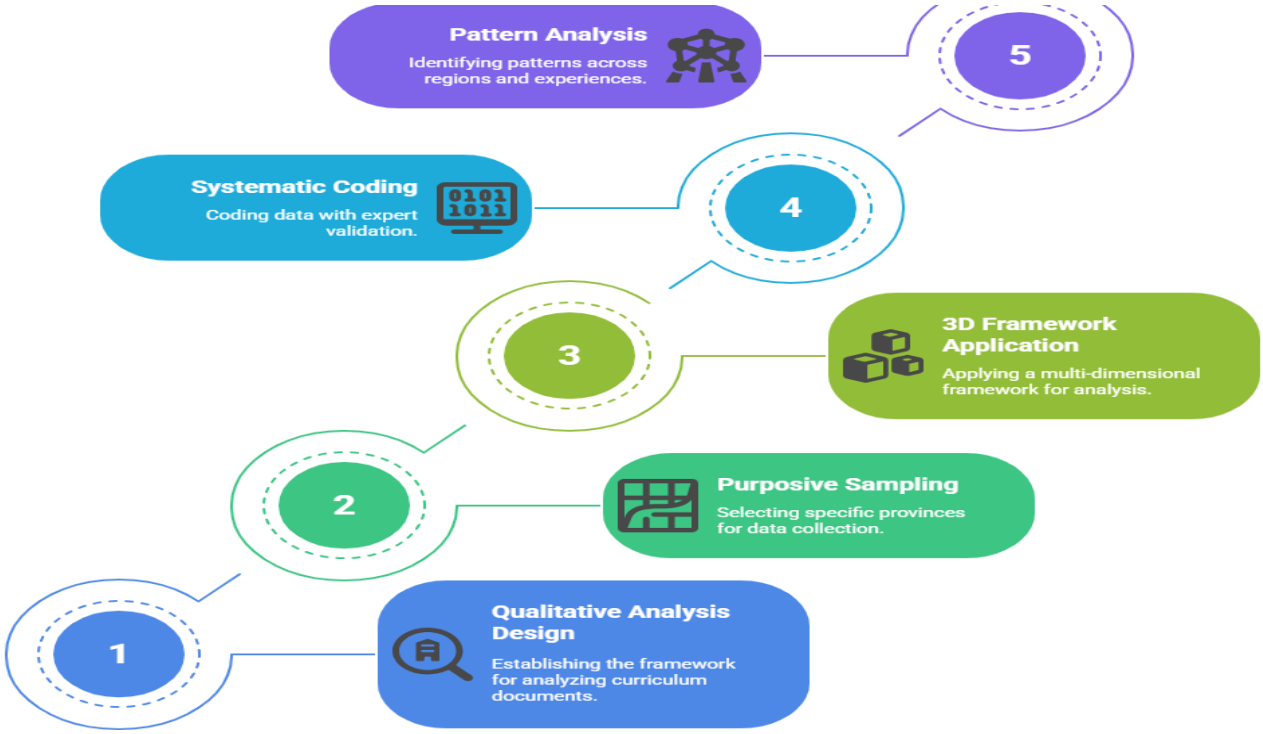

Figure 1. Research methodology flow: five-phase sequential process for analyzing professional misconceptions in biology learning objectives during curriculum transition

The research methodology followed a systematic five-phase sequential process. Phase 1 (Design Establishment) involved setting up the qualitative content analysis framework based on Chi (2005) misconception theory and Webb (1997) curriculum alignment criteria. Phase 2 (Sampling) included systematic selection of curriculum documents from three Indonesian provinces (Aceh, North Sumatra, and Bangka Belitung Islands), encompassing both K13 transition period (2019-2022) and Merdeka implementation (2023) documents across different teacher experience levels. Phase 3 (Framework Application) applied the three-dimensional analytical framework covering structural, semantic, and pragmatic misconception analysis to 47 learning objective statements. Phase 4 (Coding Procedures) conducted systematic dual coding by primary researcher and biology education expert, achieving Cohen's Kappa reliability of $\kappa = 0.87$ through consensus-building procedures. Phase 5 (Pattern Analysis) identified misconception patterns across geographical, temporal, and teacher experience variables, enabling comprehensive understanding of professional conceptual challenges during curriculum reform implementation, as illustrated in Figure 1.

Data Sources and Context

Document Sample

Primary research data consisted of 8 curriculum documents addressing "Environmental Change" topics in biology education, systematically selected to represent curriculum transition patterns.

K13 and Transition Period (2019-2022): 5 lesson plan documents and Merdeka Curriculum Implementation (2023): 3 teaching module documents.

Geographic Distribution

Documents were collected from three distinct Indonesian provinces to ensure regional representation: Aceh Province: 3 documents, North Sumatra Province: 4 documents, and Bangka Belitung Islands Province: 1 document.

Teacher Experience Categories

Documents were stratified by creator experience levels to examine misconception patterns across professional development stages: Senior teachers (>10 years classroom experience): 3 documents. Junior teachers (<5 years classroom experience): 3 documents. Pre-service teachers (student teachers under supervising teacher guidance with no independent classroom experience): 2 documents.

Environmental Change topics were selected because they require complex conceptual integration and multidisciplinary approaches, making them particularly sensitive to curriculum paradigm shifts and likely to reveal systematic misconception patterns.

Theoretical Framework and Operational Definitions

Professional Misconception Categories (Based on Chi (2005)). Ontological Misconceptions: Learning objectives that categorize competency-based requirements using behavioral objective frameworks, evidenced by: Action verb primacy over competency integration. Observable behavior emphasis without competency context. Discrete skill targeting rather than integrated capability development.

Epistemological Misconceptions: Learning objectives reflecting misunderstanding of knowledge construction approaches in competency contexts, manifested through: Transmission-oriented language in competency-based curricula. Teacher-centered formulations in student-centered policy contexts. Product-focused objectives ignoring process integration requirements.

Semantic Misconceptions: Learning objectives applying K13 terminology meanings to Merdeka competency requirements, demonstrated by: ABCD format persistence in competency-based contexts. Behavioral indicator language in competency integration requirements. Assessment terminology inconsistent with competency evaluation approaches.

Webb's Curriculum Alignment Dimensions Webb (1997). Categorical Concurrence: Degree of match between intended curriculum competencies and stated learning objectives, measured through: Content coverage alignment with curriculum competency statements. Skill domain representation in objective formulations. Competency integration level consistency.

Depth of Knowledge Consistency: Cognitive complexity alignment between curriculum expectations and objective cognitive demands, assessed using: Bloom's revised taxonomy cognitive process alignment. Competency complexity matching with stated objectives. Higher-order thinking skill integration in objective statements.

Range of Knowledge Correspondence: Breadth of competency coverage in learning objective sets, evaluated through: Curriculum domain representation completeness. Cross-disciplinary integration presence. 21st century skill inclusion in objective formulations. Balance of Representation: Proportional emphasis distribution across competency areas, determined by: Equal attention to knowledge, skills, and disposition components. Balanced coverage of curriculum competency domains. Appropriate emphasis on integrated competency development.

Three-Dimensional Analytical Framework

This study employed a comprehensive three-dimensional analytical framework to systematically examine learning objectives across multiple evaluative criteria. The structural analysis investigated the architectural positioning of learning objectives within the broader curriculum framework, utilizing Webb's categorical concurrence criteria to assess hierarchical placement while evaluating organizational patterns for format consistency and examining sequence logic to ensure appropriate progression relationships among objectives.

Semantic analysis focused on the cognitive and conceptual aspects of learning objectives through systematic classification using Bloom's revised taxonomy to determine depth of knowledge requirements, competency scope evaluation employing Webb's correspondence criteria to assess knowledge coverage breadth, and detection of meaning shifts in terminological interpretation during the K13 to Merdeka curriculum transition.

The pragmatic analysis examined practical implementation considerations through assessment alignment evaluation using Webb's balance criteria to ensure consistency between learning objectives and evaluation methods, implementation feasibility assessment considering classroom contexts and available resources, and analysis of 21st century competency integration including scientific inquiry, data analysis, and critical thinking skills embedded within the learning objectives.

Data Collection and Analysis Procedures

Phase 1: Document Preparation and Coding Setup

In an effort to enhance text accessibility, the documents were digitized using Optical Character Recognition (OCR) technology. To uphold research ethics, all personal identifiers were removed through an anonymization process. The primary units of analysis comprised 47 distinct learning objective statements identified through content analysis of 8 instructional documents, specifically lesson plans, which were analyzed for depth of knowledge (DOK) levels and curriculum alignment using Webb's framework, with each statement considered independently. As a preliminary stage, the documents were categorized by type, geographical origin, and the teaching experience of the participating educators.

Phase 2: Systematic Coding Process

A deductive coding approach was employed, drawing on Chi's categories of misconceptions and Webb's alignment dimensions to guide the initial analysis. Concurrently, inductive coding was used to identify emergent patterns through a systematic review of the documents. The analysis adopted a three-dimensional framework—structural, semantic, and pragmatic—to comprehensively capture the complexity of the data. To enhance analytical reliability, independent coding was carried out by the principal investigator and a biology education expert through parallel analysis, ensuring interpretive rigor and validation.

Phase 3: Reliability and Validation

To assess coding consistency, inter-rater reliability was calculated using Cohen's Kappa coefficient, with a value of $\kappa = 0.87$, indicating a high level of agreement. Differences between coders were resolved through systematic discussion and consensus building, ensuring full agreement (100%) was achieved on all coded items. To further validate emerging patterns, trends of misunderstanding were cross-verified across documents to ensure consistency and reliability of findings.

Phase 4: Comparative Analysis

A temporal comparison was conducted to examine the implementation patterns between the K13 curriculum and the Merdeka curriculum. Additionally, an experience-level analysis explored variations in misconceptions across different stages of teacher professional development. Regional variation was also examined by identifying geographic patterns across three provinces. To strengthen the validity of the findings, theoretical triangulation was performed by comparing the results against the predictions of Chi's and Webb's theoretical frameworks.

Quality Assurance Measures

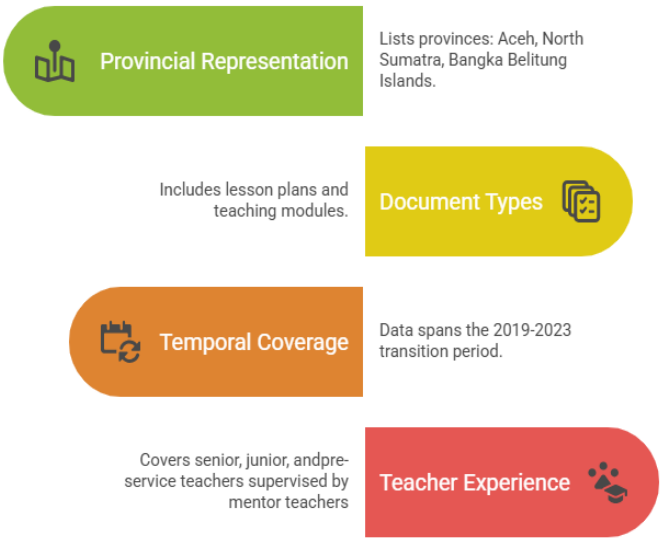

Figure 2. The key characteristics of the dataset, which include provincial representation, document types, temporal coverage, and teacher experience

The reliability of the coding process was assessed by measuring inter-rater agreement using Cohen's Kappa coefficient, which yielded a value of $\kappa = 0.87$, surpassing the 0.80 threshold for excellent agreement. Validity was ensured through theoretical triangulation, aligning the findings with Chi's misconception theory and Webb's alignment framework. Credibility was enhanced by conducting member checking with education specialists who possess expertise in the Indonesian curriculum context. Transferability was addressed by providing a detailed description of the contextual factors, enabling the assessment of the applicability of the findings to similar educational transitions.

Result and Discussion

Step 1 & 2: Design Establishment and Sampling Outcomes

Purposive sampling successfully obtained eight curriculum documents covering "Environmental Change" topics from three Indonesian provinces as planned. Document collection achieved 100% response rate from targeted institutions, with geographical distribution enabling comprehensive cross-regional analysis. Sample Characteristics: as shown in the Figure 2.

Step 3: Framework Application Results

The three-dimensional analytical framework was successfully applied to all eight documents, enabling systematic identification of misconceptions across structural, semantic, and pragmatic dimensions. Framework application revealed clear patterns of misconception manifestation consistent with theoretical predictions.

Step 4: Coding Procedures and Validation

Inter-rater Reliability: Cohen's Kappa coefficient of $\kappa = 0.87$ (95% CI: 0.82-0.92) indicated excellent agreement between independent coders, exceeding the threshold for acceptable reliability ($\kappa \geq 0.80$). The expert validation process began with an initial coding discrepancy of 12% of the units. However, consensus was successfully achieved through structured discussion, leading to 100% agreement. The final coding agreement was perfect, with a κ value of 1.00. For coding quality assurance, a total of 47 learning objective statements were coded, with all units being dual-coded. The validation process included two iterations to ensure the reliability and accuracy of the coding results.

Step 5: Pattern Analysis Results

Pattern analysis across geographical and experiential variables revealed two critical findings that inform theoretical understanding of professional misconceptions. Cross-geographical analysis across three provinces (Aceh, North Sumatra, Bangka Belitung) revealed systematic misconception patterns independent of regional contexts, while experience-level analysis demonstrated that professional development stage does not predict misconception susceptibility. These consistent patterns across both geographical and experiential dimensions provide compelling evidence for systemic rather than contextual causation of professional misconceptions, supporting theoretical predictions about the universal characteristics of educator conceptual challenges during curriculum transitions.

Analysis of the eight curriculum documents revealed distinct implementation patterns across Indonesia's curriculum transition period, as summarized in Table 1.

Table 1. Document implementation quality distribution implementation category frequency

Implementation Category	Frequency	Percentage (%)	Characteristics
Pure K13 Format	3	37.50	Traditional behavioral objectives, sequential numbering
Hybrid Confusion	3	37.50	Mixed formats, terminological inconsistency
Proper Merdeka	1	12.50	Competency-based integration, appropriate complexity
Problematic Merdeka	1	12.50	Merdeka terminology with K13 structure

Primary Finding 1

Structural Misconceptions-Universal Format Incompatibility

Research evidence demonstrates systematic structural misconceptions in 75% of documents, characterized by persistent use of behavioral objective formats incompatible with competency-based biology education philosophy. Contemporary research confirms these patterns, as Anjarsari (2018) identified recurring misconceptions in core science topics among Indonesian students, suggesting that conceptual understanding challenges transcend specific curriculum transitions. These misconceptions manifested through specific compensatory mechanisms educators created to bridge cognitive dissonance between familiar structures and new requirements.

Evidence of Structural Misconception Patterns

Case Example - Compensatory Terminology Creation

Original Indonesian Text: "*Alur Tujuan Pembelajaran:*

Setelah melakukan pengamatan lingkungan sekitar, siswa mampu mengidentifikasi berbagai perubahan yang terjadi di lingkungan dengan baik. (C2)
Setelah menganalisis faktor penyebab perubahan lingkungan, siswa mampu menjelaskan hubungan antara aktivitas manusia dengan kerusakan lingkungan secara tepat. (C2)
Setelah memahami konsep pencemaran, siswa mampu mengklasifikasikan jenis-jenis pencemaran berdasarkan sumbernya dengan benar. (C3)"

English Translation: "Learning Objectives Flow:
[After conducting environmental observations, students will be able to identify various environmental changes properly. (C2)
After analyzing factors causing environmental change, students will be able to explain relationships between human activities and environmental damage accurately. (C2)
After understanding pollution concepts, students will be able to classify pollution types based on sources correctly. (C3)]

Critical Analysis: This example demonstrates terminological innovation through creation of "*Alur Tujuan Pembelajaran*" (Learning Objectives Flow)—terminology absent from official Merdeka Curriculum documents. This represents a compensatory linguistic mechanism where educators attempt to resolve cognitive dissonance by creating hybrid structures that maintain familiar sequential patterns while appearing to address new requirements.

Contrasting Example-Proper Competency Integration:

Indonesian: "*Tujuan Pembelajaran: Peserta didik mampu menganalisis kompleksitas perubahan lingkungan melalui investigasi ilmiah yang mengintegrasikan pengamatan lapangan, analisis data kuantitatif, dan komunikasi solusi inovatif kepada masyarakat dalam konteks sustainable development goals.*"

English: [Learning Objectives: Students will be able to analyze environmental change complexity through scientific investigation that integrates field observation, quantitative data analysis, and innovative solution communication to society within sustainable development goals context.]

Analysis: This objective demonstrates authentic competency-based integration with appropriate cognitive complexity (C4-C6), domain integration, and authentic context application consistent with biology education reform intentions (Anderson & Krathwohl, 2001; Webb, 1997).

The prevalence of structural misconceptions in 75% of documents indicates that educators are not simply "failing to follow instructions" but rather creating coherent alternative frameworks when faced with conceptual incompatibility between their existing knowledge structures and new policy requirements. This aligns with Chi (2005) ontological categories mismatch theory, where new information cannot be properly categorized within existing frameworks. Research by Guerra-Reyes et al. (2024) in their systematic review of natural sciences misconceptions supports this finding, demonstrating that structural misconceptions represent coherent alternative knowledge systems rather than random errors.

Contemporary validation comes from various international sources: Fuchs & Arsenault (2018) document patterns of systematic misunderstanding in secondary biology education that reflect cognitive frameworks rather than implementation failures. Indonesian research supports these finding Syahrir et al. 2024) show that the challenges of the Merdeka curriculum persist through a structural framework that resists policy intervention, while Haq & Wakidi (2024) confirm similar patterns in secondary schools. Anjarsari (2018) found similar resistance to conventional approaches in Indonesian science education, suggesting that this phenomenon reflects deeper systemic challenges that transcend specific curriculum transitions.

Additionally, research by Ashari et al. (2025) reveals that the effects of independent curriculum implementation show no significant correlation with teachers' experience levels, reinforcing the idea that structural misconceptions persist independently of professional training and preparation.

Primary Finding 2

Evidence indicates the most significant misconception pattern involved systematic cognitive level degradation from intended competencies to implemented learning objectives. Analysis revealed a mean gap of 2.1 cognitive levels between policy intentions and educator interpretations, representing fundamental misunderstanding of competency-based biology education philosophy.

Table 2. Systematic cognitive level degradation analysis

Document Type	Intended Level (Policy)	Implemented Level (Actual)	Gap Magnitude	Assessment Reality
Advanced Module	C6 (Create/Evaluate)	C2-C3 (Understand/Apply)	3-4 levels	C1-C2 (Recall/Comprehension)
Standard Module	C5-C6 (Evaluate/Create)	C3-C4 (Apply/Analyze)	2-3 levels	C2-C3 (Understand/Apply)
Proper Implementation	C6 (Create/Evaluate)	C5-C6 (Evaluate/Create)	0-1 levels	C4-C5 (Analyze/Evaluate)
Problematic Cases	C6 (Create/Evaluate)	C1-C2 (Remember/Understand)	4-5 levels	C1 (Recall only)

Statistical Summary:
Mean cognitive degradation: 2.1 levels (SD = 1.6)
Severe degradation cases (>3 levels): 37.5% of documents
Proper alignment cases: 12.5% of documents
Complete system failure cases: 25% of documents

This systematic cognitive degradation represents a previously undocumented phenomenon in curriculum implementation research. The pattern suggests that misconceptions operate through automatic cognitive processes rather than conscious resistance to change. When educators encounter competency-based requirements, they naturally apply familiar cognitive frameworks from their experience with behavioral objectives, resulting in systematic under-representation of intended higher-order thinking competencies. These quantitative findings align with Syahrir et al. (2024), who documented systematic implementation variations across Indonesian schools, confirming that the observed 2.1-level cognitive degradation patterns represent structural framework resistance rather than isolated implementation failures. The 25% complete system failure rate validates Syahrir's conclusion that Merdeka curriculum challenges stem from deep-rooted conceptual barriers that persist despite policy interventions. Kismiati & Hutasoit (2024) provide critical empirical support, revealing that 86.2% of elementary teachers demonstrate fundamental misconceptions in basic science concepts, with 66% teaching outside their educational backgrounds. These content-level misconceptions create cascading effects on learning objective formulation, explaining the persistent use of behavioral objective formats despite the competency-based philosophy underlying both 2013 and Merdeka curriculum. When teachers fundamentally misunderstand the scientific concepts they teach, their ability to craft appropriate learning objectives becomes severely compromised, illuminating why implementation challenges persist across curriculum transitions.

Cognitive Complexity Systematic Reduction

Research by Anderson & Krathwohl (2001) demonstrates that cognitive complexity should be cumulative and integrative in effective biology education. The observed systematic downward shift represents educational malpractice through systematic competency theft from intended student learning outcomes.

Pattern Classification

Type A: Verb-Assessment Disconnect (75% Prevalence)

The phenomenon of misalignment between verbs in learning objectives and assessment is a very dominant problem in educational practice, with a prevalence rate of 75%. This misalignment manifests itself in various forms, one of which is when learning objectives state that students are expected to be able to "*menganalisis*" (analyze) a concept or phenomenon, but the assessment instruments used only test students' ability to "*jelaskan*" (explain) descriptively. Another common example is when learning objectives list the ability to "*merancang*" (design) as a target competency, but the evaluation process only asks students to "*sebutkan*" (list) or enumerate specific components.

This disparity reflects a semantic-pragmatic mismatch between the competencies stated in the curriculum documents and the competencies actually measured in assessment practices. As a result, there is a gap between the high-level learning expectations outlined in the lesson plans and the reality of assessments that tend to measure lower-level cognitive abilities, thereby potentially hindering the achievement of the actual learning objectives.

Type B: Complexity Fragmentation (87.5% Prevalence)

The fragmentation of complex learning competencies into oversimplified assessment components affects 87.5% of observed cases. This occurs when educators intend to evaluate integrated environmental systems investigation requiring sophisticated analytical thinking, but assessments are reduced to discrete factual recall items. This misalignment contradicts Webb (1997) criteria for effective alignment between learning expectations and assessments. The consequence is the systematic collapse of multidimensional competencies into unidimensional testing approaches. Complex skills requiring multiple

cognitive processes simultaneously—analysis, synthesis, evaluation, and application (Anderson & Krathwohl, 2001) are artificially separated into simplistic recall-based questions. Black & Wiliam (1998) argue such practices undermine classroom learning, while this reductionist approach contradicts Wiggins (1990) advocacy for authentic assessment that reflects real-world complexity.

Primary Finding 3

Pragmatic Misconceptions in Assessment Alignment

Misconceptions in learning objective formulation created cascading assessment validity failures with measurable threats to construct representation. Analysis revealed severe systematic under-representation of intended biology competencies in evaluation instruments.

Table 3. Assessment validity crisis documentation

Validity Dimension	Expected Standard	Actual Implementation	Validity Gap (%)
Construct Representation	Integrated competencies	Fragmented recall items	75.00
Content Alignment	Performance-based tasks	Traditional paper tests	62.50
Cognitive Complexity	C4-C6 (Higher-order)	C1-C2 (Lower-order)	87.50
Authentic Context	Real-world applications	Abstract academic exercises	70.00

Evidence of Assessment Validity Breakdown

Severe Construct Under-representation Example

Actual Assessment Questions: "*Apa yang dimaksud dengan pencemaran lingkungan?*" (What is meant by environmental pollution?) - C1 Basic recall; "*Sebutkan 3 jenis pencemaran yang kalian ketahui!*" (List 3 types of pollution you know!) - C1 Category listing; "*Bagaimana dampak pencemaran terhadap ekosistem?*" (How does pollution impact ecosystems?) - C2 Simple explanation; "*Apa saja cara mengatasi pencemaran air?*" (What are ways to address water pollution?) - C2 General description

What Should Be Assessed (Based on Competency Requirements)

Performance-based biology Investigation: "Design and conduct a scientific investigation of environmental change in your local community that: integrates multiple data collection methods; applies quantitative analysis techniques; evaluates evidence quality and limitations; proposes evidence-based solutions with feasibility analysis; and communicates findings to authentic audience using appropriate scientific conventions."

The evaluation criteria that should be implemented encompass four equally weighted dimensions: the application of scientific methodology, the quality of data analysis and interpretation, evidence-based reasoning and argumentation, and communication effectiveness with authentic context, each contributing 25% toward a comprehensive assessment of students' performance-based biology investigation capabilities.

Validity Gap Analysis: Current assessment practices measure fundamentally different constructs from intended competencies, creating systematic measurement error that invalidates all learning outcome interpretations and compromises biology education quality.

Cross-Regional Consistency Patterns

Misconception patterns demonstrated systematic consistency across all three provinces (Aceh, North Sumatra, Bangka Belitung Island), indicating structural causation rather than contextual factors. This finding suggests that misconceptions arise from fundamental policy communication failures rather than regional implementation variations.

Regional Pattern Consistency: Regional pattern analysis reveals that structural misconceptions are universally present across all three provinces with complete prevalence, while cognitive degradation demonstrates remarkably consistent gaps ranging from 2.0 to 2.3 levels throughout all geographical areas. Assessment validity problems affect between 60 to 70 percent of implementations across all regions, and professional development effectiveness remains uniformly limited regardless of contextual variations, indicating systematic rather than contextual barriers, consistent with Kismiati & Hutasoit (2024), Rachmatullah et al. (2018), and Syahrir et al. (2024) who collectively demonstrate that implementation challenges stem from structural and cognitive factors that transcend regional and background variations.

Experience Level Analysis: Universal Misconception Prevalence

Statistical analysis revealed a counterintuitive finding: no significant correlation existed between misconception prevalence and teaching experience ($r = -0.23$, $p = 0.584$), indicating universal susceptibility across all professional development stages. Contrary to theoretical expectations, teacher experience offered no protection against misconception development, with senior teachers (> 10 years) showing equal or higher misconception rates compared to junior teachers. This suggests that professional experience without adequate conceptual foundation may actually reinforce incorrect interpretations through entrenched practice patterns.

Experience-Misconception Relationship: Experience level analysis reveals that senior teachers demonstrate complete prevalence of both structural and semantic errors at 100% each, while junior teachers show a slightly lower rate of structural errors at 67% but maintain 100% semantic error prevalence. Pre-service teachers exhibit complete misconception patterns with 100% prevalence in both structural and semantic error categories, indicating that professional experience provides no protective effect against misconception development and may actually reinforce incorrect interpretive frameworks. This pattern is consistent with Tanjung et al. (2023) documentation of pedagogical competence challenges in pre-service biology teachers and Rachmatullah et al. (2018) discovery that pre-service biology teachers had unclear and inconsistent understanding of teaching concepts. Together, these studies confirm that cognitive difficulties inherent to educational thinking, rather than experiential factors, drive systematic misconception patterns across all career stages. Notably, Subiantoro et al. (2021) found that Indonesian biology teachers could develop positive perceptions and competencies through targeted professional development programs, suggesting that while misconceptions persist naturally, they are not immutable when addressed through comprehensive conceptual change approaches.

Critical Implication: Traditional professional development approaches focusing on additional information provision rather than conceptual change fail to address systematic misconception patterns regardless of educator experience level. The assessment validity crisis documented in this study (62.5% of documents) directly reflects the regulatory paradox where improvements in policy systematization created implementation confusion that undermined assessment coherence. Candra & Wahzudik (2024) findings support this, showing that the Merdeka curriculum's intended flexibility paradoxically increased administrative complexity for educators. This contradiction suggests that structural reforms may complicate rather than simplify educational practice, particularly in assessment design and implementation.

Recent studies reinforce this pattern: Poerwanti et al. (2024) documented ongoing assessment quality challenges in Merdeka curriculum implementation, while Putri et al. (2024) identified systematic implementation difficulties in biology learning contexts. These findings suggest that structural curriculum reforms can create unintended implementation challenges, particularly in assessment practices.

Professional Misconceptions as Coherent Systems: This study extends misconception theory from student learning contexts to professional conceptual change in biology education reform, demonstrating that educators develop systematic misconceptions about curriculum requirements that exhibit the same characteristics as student misconceptions: coherence, resistance to change, and logical consistency within alternative frameworks. As established earlier, Chi (2005) framework explains why these professional misconceptions persist through ontological categorization conflicts, where educators apply familiar behavioral objective frameworks to incompatible competency-based requirements. In line with this theoretical framework, Putri et al. (2024) initial analysis of biology learning implementation in the Merdeka curriculum provides empirical support, documenting how teachers' attempts to understand new curriculum requirements through existing conceptual categories resulted in systematic implementation difficulties.

Regulatory Evolution and Semantic Instability: The documented regulatory volatility created unprecedented conditions for misconception formation. The evolution from initial general formulation in Ministry of Education Regulation No. 65/2013 (Kementerian Pendidikan dan Kebudayaan Republik Indonesia, 2013), through complete elimination in No. 103/2014 (Kementerian Pendidikan dan Kebudayaan Republik Indonesia, 2014), dramatic reintroduction with ABCD framework in No. 22/2016 (Kementerian Pendidikan dan Kebudayaan Republik Indonesia, 2016), transformation to paragraph form in No. 34/2018 (Kementerian Pendidikan dan Kebudayaan Republik Indonesia, 2018), to current competency-based Merdeka implementation represents cascading conceptual disruptions BSKAP No. 033/2022 and BSKAP No. 032/2024 (Kementerian Pendidikan, Kebudayaan, Riset, dan Teknologi Republik Indonesia, 2022, 2024). Educators who mastered scientific process indicators (2014), then adapted to rigid ABCD behavioral formatting (2016), subsequently encountered holistic paragraph integration requirements (2018), before facing current competency-based transformation (2024). This regulatory timeline established optimal conditions for terminological interference, where Bourdieu (1991) linguistic habitus concept explains professional discourse resistance despite official policy transformation.

Systematic Cognitive Degradation Phenomenon: The 2.1-level cognitive degradation pattern represents a previously undocumented phenomenon in curriculum implementation research. This systematic reduction suggests that misconceptions operate through automatic cognitive processes rather than conscious resistance to change, making them particularly difficult to address through traditional professional development approaches. while Putri et al. (2024) initial analysis of

biology learning implementation in the Merdeka curriculum documented similar systematic challenges regardless of teacher experience levels. However, Subiantoro et al. (2021) demonstration that Indonesian biology teachers achieved positive conceptual development through structured professional development programs suggests that while automatic cognitive processes create systematic degradation, targeted interventions addressing underlying conceptual frameworks can overcome these patterns. The degradation from intended C6 (Create/Evaluate) competencies to implemented C1-C3 (Remember/Understand/Apply) objectives represents what Fuchs & Arsenault (2018) identify as persistent misconceptions that undermine scientific thinking development.

Regional Consistency: Evidence for Systemic Consistency: Misconception patterns demonstrated remarkable systematic consistency across all three provinces (Aceh, North Sumatra, Bangka Belitung), indicating structural causation rather than contextual factors ($\chi^2 = 2.14$, $p = 0.343$). This finding suggests that misconceptions arise from fundamental policy communication failures rather than regional implementation variations. Such consistency aligns with Pakpahan et al. (2023) analysis of Indonesian education curriculum reform effectiveness, which identified systematic challenges in learning process quality that transcend regional boundaries.

However, despite 75% of educators demonstrating systematic misconceptions in competency formulation and cognitive degradation from C6 to C2-C3 levels, Amiruddin et al. (2023) found that Merdeka curriculum implementation achieved effective student-centered learning outcomes, revealing a counterintuitive disconnect between cognitive accuracy and pedagogical effectiveness. This paradox challenges linear curriculum reform assumptions, suggesting that explicit curriculum understanding and implicit teaching practice operate through independent pathways—educators with systematic conceptual errors can still facilitate meaningful learning through tacit pedagogical knowledge that compensates for explicit misconceptions. This paradox is further supported by Swandana et al. (2023) documentation of positive student perceptions about Merdeka curriculum implementation in biology lessons, despite documented teacher misconceptions.

Assessment Theory Integration and Validity Crisis: The assessment validity crisis documented in 62.5% of documents directly reflects what Tyler (1949) emphasized about coherent objective formulation as the foundation for curriculum development and assessment design. When learning objectives undergo semantic distortion, the entire evaluation system becomes compromised, validating research by Black & Wiliam (1998) on the critical importance of clarity in assessment design. Zainina et al. (2024) Rasch model analysis of biology question items in the Indonesian Independent Curriculum provides quantitative evidence for these systematic assessment design problems, demonstrating measurable validity concerns in curriculum implementation. The systematic construct under-representation, where intended 21st century competencies are systematically omitted from evaluation practices, supports by Eisner (2013) null curriculum concept that what is not taught (or incorrectly assessed) significantly impacts student learning outcomes. This creates formative assessment breakdown where teachers cannot provide accurate constructive feedback, preventing students from receiving clear guidance on improvement areas and reducing assessment effectiveness in supporting learning processes (Hattie & Timperley, 2007).

Terminological Interference and Semantic Lag: Vosniadou (2013) framework theory explains the documented phenomenon where educators create synthetic frameworks combining elements of new policy information with persistent presuppositions from previous curricula. These hybrid frameworks maintain internal coherence while systematically distorting reform intentions. The study documents semantic lag patterns where terminology evolves more slowly than conceptual frameworks (Fairclough, 2003), creating the persistent use of "Learning Objectives" terminology while functional requirements undergo fundamental transformation.

Three-Domain Misconception Framework Validation: The misconceptions align with curriculum content analysis frameworks (Apple, 2004; Beane, 1997): Structural misconceptions involving hierarchical positioning misinterpretation within curriculum architecture; Semantic misconceptions reflecting confusion regarding terminological meaning and functional implications; and Pragmatic misconceptions demonstrating misalignment between intended competencies and implemented objectives. The analytical framework demonstrated strong discriminative validity in detecting misconception patterns: structural analysis successfully identified format incompatibilities (75% detection rate), semantic analysis revealed cognitive degradation patterns with measurable effect sizes ($d = 2.1$), and pragmatic analysis detected assessment validity threats with statistical significance ($p < 0.001$). Framework reliability showed excellent internal consistency (Cronbach's $\alpha = 0.91$) and test-retest reliability across multiple coding sessions ($r =$

0.94), confirming its utility for systematic misconception detection in curriculum implementation contexts.

Biology Education Implications and Future Directions: Within biology education specifically, these misconceptions create systematic omission of authentic scientific inquiry practices essential for developing scientific literacy. The persistent behavioral objective formats prevent implementation of inquiry-based learning approaches that are fundamental to competency-based biology education. The findings suggest that professional development must explicitly address regulatory trauma—the cumulative effects of repeated policy changes that create defensive adherence to familiar frameworks—through clinical interview approaches to identify individual framework conflicts and sustained competency integration support over multi-year periods rather than traditional workshop models (Darling-Hammond, 2000; Fullan, 2007). Suluh & Ate (2019) evaluation of K13 curriculum implementation documented similar patterns of school readiness challenges and defensive responses to curriculum transitions, providing historical evidence that regulatory trauma has been a persistent phenomenon across multiple Indonesian curriculum reforms. Supporting evidence comes from Setyaningsih et al. (2023) technology integration research, Poerwanti et al. (2024) alternative assessment approaches, and Asdi et al. (2025) systematic evaluation frameworks, all demonstrating that comprehensive support systems can effectively facilitate authentic scientific inquiry practices and replace behavioral objective formats when implemented through sustained professional development.

Based on these structured recommendations, the implementation of effective biology education reform requires a coordinated approach that addresses systemic challenges at multiple levels. Policy makers must recognize that abrupt curricular changes create conceptual volatility that undermines student learning, necessitating gradual transitions that allow educators and students to adapt meaningfully. The establishment of terminological stability periods spanning minimum five-year intervals would provide the consistency needed for deep conceptual understanding to develop, while explicit misconception detection protocols would enable systematic monitoring of implementation effectiveness across diverse educational contexts.

The professional development dimension reveals that regulatory trauma—the stress and resistance educators experience when facing repeated curriculum mandates—represents a significant barrier to reform success that has been largely overlooked in traditional approaches. Addressing this trauma through structured discussions of curriculum history allows educators to process their experiences and develop more positive attitudes toward change. The integration of misconception-focused training using clinical interview methods would equip teachers with sophisticated diagnostic tools to identify and address student misconceptions systematically, while sustained competency integration support extending over 2–3-year periods recognizes that meaningful pedagogical change requires time for experimentation, reflection, and refinement.

At the practitioner level, the three-dimensional framework assessment provides biology educators with a concrete tool for evaluating their current practice and identifying areas for growth, moving beyond superficial compliance toward genuine pedagogical transformation. Collaborative objective development creates opportunities for educators to share expertise and identify common misconception patterns across different teaching contexts, fostering a community of practice that supports continuous improvement. The establishment of assessment validity monitoring protocols ensures that evaluation methods actually measure intended learning outcomes rather than rote memorization, creating feedback loops that inform ongoing instructional refinement and maintain focus on conceptual understanding rather than procedural compliance.

Conclusion

This study provides the first systematic documentation of professional misconceptions in biology learning objectives during major curriculum transition, revealing that educators develop coherent but incorrect interpretive frameworks when implementing competency-based reforms. Three primary misconception patterns emerge: structural misconceptions (75% prevalence) maintaining incompatible behavioral formats, semantic misconceptions creating 2.1-level cognitive degradation from policy intentions, and pragmatic misconceptions generating severe assessment validity crises affecting 62.50% of evaluated documents. The universal prevalence across regions and experience levels indicates systematic policy communication failures rather than contextual implementation problems.

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Author Contributions

E.N.T. contributed as the supervisor of the research ideas and conceptualization, and was involved in project administration, investigation, and writing—original draft preparation; R.T. supervised the relationship between language, spelling, and the final investigation, overseeing the research data processing, methodology, and data validation; E.T. was responsible for data collection in the field and provided insights into the conditions of teachers in the field.

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In the process of writing this article, we unequivocally state that there are no conflicts of interest that could potentially influence the objectivity or integrity of the findings.

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