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Conceptual errors and cross-representational inconsistencies in an indonesian primary science textbook on insect metamorphosis

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Abstract

Background: Conceptual errors and inconsistencies across textual, visual, and assessment components may undermine the scientific accuracy and instructional coherence of primary science textbooks, particularly when explaining insect metamorphosis.
Aims: This study identified conceptual errors, examined cross-representational inconsistencies, and investigated how assessment items reproduced inaccuracies in an Indonesian Grade III supplementary science textbook.
Method: Qualitative content analysis examined a purposively selected chapter emphasizing insect metamorphosis. Text, illustrations, and assessments were coded using established error classifications and theoretically derived categories for internal contradictions and assessment misalignment. Findings were verified against independent entomological references and reviewed through peer debriefing.
Results: Thirty-three coded instances were identified: 18 textual, six visual, and nine assessment-related findings. These comprised misidentification (13), assessment misalignment (11), internal contradictions (5), oversimplification (3), and undergeneralization (1). Major issues involved incorrect metamorphosis classifications, inconsistent developmental terminology, contradictory illustrations, and assessment items containing conceptual inaccuracies, ambiguous answers, or editorial errors.
Conclusion: The analyzed chapter exhibited interconnected conceptual and representational deficiencies. Improvements require accurate biological classifications, consistent terminology, coordinated text–visual revisions, and systematic assessment validation to strengthen instructional coherence and scientific accuracy.

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INTRODUCTION

Conceptual accuracy in primary science textbooks is fundamental to the development of scientific understanding, particularly when instructional materials introduce biological processes that require precise explanations and classifications. Scientifically inaccurate information may compromise the reliability of learning resources by presenting explanations that conflict with established biological knowledge (Papaneophytou & Nicolaou, 2025; Potvin, 2023; Sert et al., 2020). Previous investigations have documented conceptual inaccuracies in science textbooks, demonstrating the importance of systematic content evaluation to ensure the scientific reliability of

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instructional materials (Fakhriyah et al., 2025; Maknun et al., 2025). In Indonesian primary education, science and social studies are integrated within *Ilmu Pengetahuan Alam dan Sosial* (IPAS), supported by core textbooks and supplementary materials containing textual explanations, illustrations, and assessment activities. These materials may also inform instructional planning and professional discussions within *Kelompok Kerja Guru* (KKG), which serves as a professional collaboration forum for primary school teachers. Ministerial Regulation No. 22 of 2022 establishes quality standards concerning the content, presentation, design, and graphical features of educational books, providing a regulatory foundation for evaluating textbook quality (Ministry of Education, Culture, Research, and Technology, 2022). Within this framework, scientific accuracy and consistency among instructional components constitute relevant considerations for evaluating whether educational materials communicate reliable and coherent scientific information. Multimedia learning theory suggests that textual and visual representations can facilitate understanding when relevant information is appropriately selected, organized, and integrated in ways that support meaningful cognitive processing (Mayer, 2020). Similarly, the Design, Functions, Tasks (DeFT) framework explains that multiple representations may complement information, constrain interpretation, and support deeper conceptual understanding when their relationships are sufficiently clear to learners. Consequently, evaluating primary science textbooks requires attention not only to the accuracy of individual explanations but also to the coherence of textual, visual, and assessment components that collectively communicate scientific concepts.

Conceptual errors embedded in instructional materials should be distinguished from students' misconceptions because the former concern inaccuracies in educational content, whereas the latter refer to learners' conceptions that diverge from accepted scientific explanations. Conceptual change theory suggests that learners interpret new scientific information through existing knowledge structures, indicating that inaccurate instructional explanations may interact with prior conceptions rather than independently determine learning outcomes (Posner et al., 1982; Thomas & Kirby, 2020; Mason & Zaccoletti, 2021). A systematic review of natural science learning identified instructional resources, teaching practices, and prior experiences as potential contributors to conceptual difficulties, emphasizing the complex origins of scientific misunderstandings (Guerra-Reyes et al., 2024). To examine inaccuracies within instructional materials, Hershey's (2004) classification provides an analytical foundation for identifying misidentification, oversimplification, overgeneralization, undergeneralization, and obsolete scientific terminology. Although these categories facilitate systematic identification of conceptual errors, they do not independently account for contradictions between textual and visual representations or discrepancies between instructional explanations and assessment items. Recent research on multimodal science textbooks has examined the organization, functions, and integration of written explanations and visual representations, highlighting the importance of representational relationships in communicating scientific knowledge (Tang, 2023a, 2023b; Park et al., 2025). Such findings indicate that the educational value of diagrams depends not merely on their inclusion but also on their scientific accuracy, explanatory functions, and compatibility with accompanying textual information. Furthermore, investigations of instructional alignment have emphasized the importance of coherence among learning objectives, instructional activities, and assessment practices in science education (Gao et al., 2020; Zhao et al., 2023). Nevertheless, assessment items containing inaccurate scientific classifications, ambiguous answer options, or contradictions with instructional explanations may compromise the accuracy and coherence of textbook-based evaluation. Therefore, integrating conceptual error classification with analyses of representational consistency and assessment alignment offers a more comprehensive perspective on textbook quality than examining textual inaccuracies in isolation.

Insect metamorphosis provides a particularly relevant context for examining these issues because understanding insect development requires accurate differentiation between developmental patterns, morphological transformations, and stage-specific biological terminology. Complete metamorphosis, or holometaboly, involves egg, larval, pupal, and adult stages, whereas incomplete metamorphosis, or hemimetaboly, involves egg, nymphal, and adult stages without a pupal stage (Chou et al., 2020). These developmental patterns describe biological transformations and should not be confused with taxonomic classifications, which concern the systematic grouping of organisms according to their evolutionary relationships. Research on insect-related science education has investigated biological representations, instructional activities, and approaches to developing understanding of insect diversity and life cycles (Menendez et al., 2020; Wommer et al., 2023). However, inaccurate developmental terminology, incorrectly classified examples, and contradictory life-cycle diagrams may reduce the conceptual coherence of instructional materials without necessarily demonstrating corresponding misconceptions among learners. Such concerns are relevant to Indonesian Grade III IPAS instruction, where biological life cycles are addressed within Phase B learning outcomes under the Merdeka Curriculum (BSKAP, 2024). Previous Indonesian textbook studies have documented conceptual inaccuracies in Grade IV and Grade VI IPAS materials, while international research has examined multimodal textbook representations and instructional alignment (Fakhriyah et al., 2025; Maknun et al., 2025; Tang, 2023a, 2023b; Park et al., 2025; Zhao et al., 2023). Nevertheless, the intersection of conceptual errors, cross-representational inconsistencies, and assessment deficiencies within locally developed Indonesian primary supplementary science textbooks remains insufficiently examined in the literature considered. Addressing this analytical gap requires an integrated examination of whether scientific inaccuracies occur independently within textual explanations or are reproduced, contradicted, or legitimized through visual representations and assessment items. Accordingly, investigating insect metamorphosis content through an integrated textbook analysis can provide context-specific evidence concerning the relationships among scientific accuracy, representational coherence, and assessment quality in primary science instructional materials.

Previous research has extensively examined conceptual difficulties and conceptual change in science education, emphasizing the cognitive mechanisms underlying students' misconceptions and the effectiveness of instructional interventions (Guerra-Reyes et al., 2024; Mason & Zaccoletti, 2021; Pacaci et al., 2024; Thomas & Kirby, 2020). Other studies have investigated multimodal representations in science textbooks, highlighting the organization, integration, and complementary functions of textual explanations and visual illustrations in supporting scientific understanding (Park et al., 2025; Tang, 2023a, 2023b). Similarly, research on instructional alignment has emphasized the importance of coherence among learning objectives, instructional activities, and assessment practices (Gao et al., 2020; Zhao et al., 2023). Studies addressing insect-related science education have further explored visual learning, biological concept development, and instructional strategies for understanding insect life cycles and metamorphosis (Menendez et al., 2020; Wommer et al., 2023). Nevertheless, these research strands have largely addressed conceptual understanding, representational coherence, and assessment alignment as separate analytical concerns, leaving the relationships among conceptual errors, contradictory representations, and assessment deficiencies within primary science textbooks insufficiently explored. This limitation is particularly relevant to Indonesian supplementary science textbooks, where the consistency of scientific explanations, biological illustrations, and assessment items requires closer examination. Addressing this gap, the present study integrates conceptual error identification with cross-representational and assessment analysis to investigate how inaccuracies in insect metamorphosis content coexist across textual, visual, and evaluative components, thereby providing empirical evidence to inform improvements in textbook accuracy and instructional coherence.

This study aims to identify conceptual errors and examine cross-representational inconsistencies in insect metamorphosis content presented in an Indonesian Grade III supplementary science textbook. Specifically, the first objective is to identify and classify scientifically inaccurate textual explanations concerning developmental stages, metamorphosis patterns, and biological terminology. The second objective is to investigate inconsistencies between textual descriptions and visual representations, including contradictions involving life-cycle sequences, developmental labels, and accompanying illustrations. The third objective is to evaluate assessment items to determine whether their questions, answer options, and implied answer keys reproduce conceptual errors, contradict instructional explanations, or contain deficiencies affecting assessment accuracy and alignment. These objectives are addressed through qualitative document content analysis of a purposively selected textbook chapter in which insect metamorphosis constitutes the principal instructional topic. The analysis employs established conceptual error categories and incorporates internal contradiction and assessment misalignment as supplementary operational categories informed by representational coherence and instructional alignment perspectives. Rather than proposing an entirely new theoretical classification, these additional categories facilitate the identification of inconsistencies that extend beyond isolated factual inaccuracies. Scientific accuracy is evaluated against established entomological references, while relationships among textual, visual, and assessment components are examined to identify interconnected instructional deficiencies. By integrating these analytical dimensions, the study contributes empirical evidence concerning how conceptual errors and representational inconsistencies coexist within supplementary science materials without assuming that their presence necessarily produces measurable student misconceptions. Ultimately, the findings are intended to inform targeted textbook improvements involving accurate metamorphosis classifications, consistent developmental terminology, scientifically coherent illustrations, and assessment items aligned with validated biological concepts.

LITERATURE REVIEW

Conceptual accuracy constitutes a fundamental dimension of science textbook quality because instructional materials are expected to communicate scientific knowledge consistently with established disciplinary explanations. In primary science education, textbooks function not only as sources of factual information but also as structured representations through which learners encounter scientific terminology, classifications, and explanatory relationships (Gizaw & Sota, 2023; Salloum, 2021; Tang, 2023b). Conceptual errors arise when instructional content misrepresents scientific phenomena, applies inappropriate terminology, or presents explanations that conflict with accepted disciplinary knowledge (Choi, 2025; Guerra-Reyes et al., 2024; Serrano, 2026; Yoon et al., 2023). Such inaccuracies differ from students' misconceptions, which refer to conceptual understandings held by learners rather than errors embedded in educational materials. Research on conceptual change emphasizes that scientific understanding develops through interactions between existing knowledge and new instructional information, making the quality of learning resources an important consideration in science education (Thomas & Kirby, 2020; Mason & Zaccoletti, 2021). A systematic review by Guerra-Reyes et al. (2024) identified instructional resources among the potential contributors to misconceptions in natural science learning, indicating that conceptual difficulties may originate from multiple interacting educational factors. Hershey (2004) proposed a classification of textbook-related conceptual problems encompassing misidentification, oversimplification, overgeneralization, undergeneralization, and obsolete scientific concepts or terminology. This classification provides an analytical foundation for distinguishing different forms

of scientific inaccuracy rather than treating all textbook errors as equivalent. Recent investigations of Indonesian primary science textbooks have identified conceptual inaccuracies in IPAS learning materials, demonstrating the relevance of systematic content evaluation within the national educational context (Fakhriyah et al., 2025; Maknun et al., 2025). Accordingly, evaluating conceptual accuracy requires a theoretically informed classification system supported by authoritative scientific references and careful differentiation between instructional errors and empirically demonstrated learner misconceptions.

The communication of scientific concepts through textbooks involves multiple representational modes, particularly written explanations, diagrams, illustrations, labels, and captions. Multimedia learning theory suggests that combining verbal and pictorial information can support understanding when learners are able to select relevant information, organize it coherently, and integrate it with existing knowledge (Mayer, 2020). The Design, Functions, Tasks framework further explains that multiple representations can complement one another, constrain interpretation, and support the construction of deeper conceptual relationships (Ainsworth, 2006). These perspectives indicate that the educational effectiveness of multimodal materials depends on the relationships among representations rather than the mere presence of different presentation formats. Research on science textbooks has examined how diagrams and written explanations are organized to communicate scientific information and support interpretation (Tang, 2023a, 2023b). Similarly, Park et al. (2025) investigated the complementary functions of visual and written representations, emphasizing the importance of examining their relationships within instructional materials. Cross-representational inconsistencies occur when different components communicate incompatible scientific information, such as when a diagram contradicts its accompanying explanation or when developmental labels differ across illustrations. Such contradictions may create interpretive ambiguity because learners encounter competing representations of the same biological phenomenon. However, the presence of contradictory information in a textbook does not independently establish how learners interpret that information or whether measurable misconceptions subsequently develop. Therefore, textbook evaluation should examine both the scientific accuracy of individual representations and the coherence of the relationships connecting textual and visual information.

Assessment alignment represents another important dimension of instructional quality because assessment items are expected to evaluate knowledge and competencies consistent with the concepts presented in learning materials. Research on science education has emphasized the importance of coherence among learning objectives, instructional activities, and assessment practices in supporting meaningful evaluation (Gao et al., 2020; Zhao et al., 2023). Within textbooks, this coherence requires assessment questions, answer options, and implied answer keys to reflect scientifically accurate explanations and appropriate conceptual distinctions. Assessment misalignment may occur when questions introduce information inconsistent with the instructional text, reproduce inaccurate classifications, or require responses that cannot be justified using accepted scientific knowledge. Such deficiencies differ from ordinary editorial errors because they concern the conceptual correspondence between instructional explanations and the knowledge being evaluated. Ambiguous answer options may further complic assessment interpretation when multiple responses are scientifically defensible or when the intended answer depends on an inaccurate textbook statement (de Ruiter et al., 2023; Qin et al., 2026). In biological education, assessment accuracy is particularly important when questions require learners to distinguish developmental processes, identify organism characteristics, or interpret life-cycle diagrams. Although instructional alignment has been examined across various educational settings, its application to the internal consistency of textbook explanations and assessment items represents a distinct analytical concern. Integrating assessment analysis with conceptual error identification and

representational evaluation can reveal whether scientific inaccuracies remain confined to explanatory content or are reproduced in evaluative activities. Consequently, a comprehensive textbook analysis should consider assessment items as interconnected instructional representations rather than isolated instruments for measuring learning outcomes.

Insect metamorphosis provides a biologically relevant context for examining conceptual accuracy because its explanation depends on distinguishing developmental stages, morphological transformations, and different patterns of postembryonic development. Complete metamorphosis, or holometaboly, generally involves egg, larval, pupal, and adult stages, whereas incomplete metamorphosis, or hemimetaboly, involves egg, nymphal, and adult stages without a pupal stage (Gullan & Cranston, 2014; Truman & Riddiford, 1999). These developmental patterns describe biological processes and should not be interpreted as interchangeable taxonomic categories or generalized to all organisms undergoing developmental changes. Accurate explanations therefore require appropriate identification of insect examples, consistent terminology, and biologically valid descriptions of developmental transitions. Confusion between larvae and nymphs, incorrect identification of pupal stages, or inappropriate classification of insect species may reduce the scientific coherence of instructional materials. Similarly, diagrams that omit essential developmental stages or employ inconsistent labels may communicate explanations that conflict with accompanying textual descriptions. Research on biological learning has examined how visual characteristics influence the interpretation of developmental processes, highlighting the relevance of representational design in explaining biological change (Menendez et al., 2020). Other studies have investigated insect-related instructional activities and educational approaches intended to strengthen understanding of insect diversity and biological concepts (Sitar et al., 2023; Wommer et al., 2023). Nevertheless, research addressing insect education and visual learning does not necessarily provide evidence concerning the scientific accuracy and internal consistency of existing textbook explanations. Accordingly, evaluating insect metamorphosis in primary science textbooks requires the integration of entomological accuracy, developmental terminology, and cross-representational consistency within a unified analytical perspective.

The quality of supplementary science textbooks should be examined in relation to their conceptual accuracy, representational coherence, and alignment with intended learning content. In Indonesia, the Merdeka Curriculum integrates natural and social sciences through IPAS, creating opportunities for biological concepts to be presented through contextual explanations, illustrations, and learning activities (BSKAP, 2024). Ministerial Regulation No. 22 of 2022 establishes standards for educational books concerning content, presentation, design, and graphical quality, providing a regulatory context for evaluating instructional materials (Ministry of Education, Culture, Research, and Technology, 2022). Previous Indonesian studies have documented conceptual inaccuracies in government-published IPAS textbooks, including problems involving scientific classifications and explanatory precision (Fakhriyah et al., 2025; Maknun et al., 2025). International investigations have separately contributed perspectives on conceptual difficulties, multimodal representations, and instructional alignment, offering complementary theoretical foundations for evaluating textbook quality (Guerra-Reyes et al., 2024; Tang, 2023a, 2023b; Park et al., 2025; Zhao et al., 2023). However, these research perspectives do not automatically establish how conceptual inaccuracies interact with contradictory illustrations and assessment deficiencies within a particular supplementary textbook. An integrated analytical framework can address this issue by combining established conceptual error classifications with operational categories for internal contradictions and assessment misalignment. Such an approach enables systematic examination of whether inaccurate biological explanations are repeated, contradicted, or left unresolved across textual, visual, and assessment components. Applied to insect metamorphosis, this perspective provides a basis for evaluating the consistency of developmental terminology, organism classifications, life-cycle representations, and assessment

questions against established entomological knowledge. Thus, the present study positions conceptual accuracy and cross-representational consistency as interconnected dimensions of primary science textbook quality, contributing a focused analytical perspective for identifying and addressing instructional deficiencies.

METHOD

Research Design

This study employed qualitative document content analysis to systematically identify and interpret conceptual errors and cross-representational inconsistencies in an Indonesian primary science textbook. The methodological approach was informed by Krippendorff's (2018) content analysis framework, which emphasizes systematic unit identification, coding, interpretation, and the development of contextually grounded inferences from recorded communication. This approach was appropriate because the research examined the scientific accuracy and internal consistency of existing instructional materials rather than students' conceptual understanding or learning outcomes. The analysis combined deductive coding based on established categories of conceptual inaccuracies with supplementary operational categories addressing internal contradictions and assessment misalignment. The conceptual classification was adapted from Hershey (2004), while the examination of relationships among textual and visual representations was informed by the Design, Functions, Tasks framework (Ainsworth, 2006) and multimedia learning principles (Mayer, 2020). These perspectives provided complementary analytical foundations for evaluating scientific accuracy, representational coherence, and assessment alignment. The study was bounded to one textbook chapter to enable detailed examination of relationships among instructional components within a shared conceptual context. Accordingly, the findings were interpreted as evidence of textbook-level inaccuracies and inconsistencies rather than as indicators of empirically demonstrated student misconceptions.

Participants and Object of Analysis

The study did not involve human participants because its primary data consisted exclusively of documentary materials. The research object was a Grade III supplementary textbook for *Ilmu Pengetahuan Alam dan Sosial* (IPAS), compiled by a district-level teacher community in East Java, Indonesia, and published in June 2026. The textbook was selected through purposive document sampling based on its educational level, supplementary instructional function, inclusion of insect metamorphosis content, and availability of textual explanations, visual representations, and assessment activities. The analysis focused on Chapter 2, *Ayo Mengenal Siklus pada Makhluk Hidup* (Let's Get to Know the Life Cycles of Living Things), covering pages 22–41. The chapter contained three instructional subchapters, three subchapter summative assessments, and one chapter-level summative assessment. Insect metamorphosis was selected as the focal content because it provided opportunities to examine developmental classifications, biological terminology, life-cycle illustrations, and related assessment items within the same instructional context. The proportion of chapter content specifically addressing insect metamorphosis was [information required: number of relevant pages or units and their proportion of the chapter]. Restricting the investigation to this chapter enabled an in-depth examination of relationships among textual, visual, and assessment components, although it limited the transferability of findings to other textbook chapters or publications. The inclusion criteria comprised instructional units directly addressing insect metamorphosis or providing biological explanations necessary for interpreting the selected metamorphosis content. Materials unrelated to the research focus were excluded from conceptual

error coding, while relevant contextual information was retained when necessary to interpret relationships among instructional components.

Instruments and Data Collection

The primary research instrument was a structured document-analysis matrix designed to record conceptual inaccuracies, representational inconsistencies, and assessment-related deficiencies. The matrix contained fields for page location, unit identification, instructional component, original content, scientific reference, identified discrepancy, primary code, secondary code where applicable, and proposed conceptual correction. Three types of analytical units were examined: textual propositions, visual representations, and assessment items. A textual proposition was defined as the smallest meaningful statement expressing a scientifically assessable claim, with sentences containing multiple independent biological claims segmented into separate units. Visual units comprised individual diagrams, illustrations, labels, and captions, which were examined for developmental sequence accuracy, organism identification, morphological correspondence, and consistency with related textual explanations. Missing captions or source information were recorded as editorial observations and were not automatically classified as conceptual errors unless they affected the scientific interpretation of the visual material. Assessment units comprised individual questions together with their answer options and implied answer keys, which were evaluated for scientific correctness, conceptual clarity, and consistency with the instructional content. The scientifically defensible answer to each assessment item was determined through comparison with established entomological explanations rather than relying exclusively on the textbook's intended answer. Scientific verification was guided by Gullan and Cranston (2014) and Truman and Riddiford (1999), with attention to developmental stages, morphological characteristics, and the distinction between holometabolous and hemimetabolous insects. Data collection involved systematically examining the selected chapter, recording relevant units in the analysis matrix, and documenting discrepancies supported by textual or visual evidence.

Table 1. Biological reference criteria for evaluating insect metamorphosis

Aspect	Holometabolous insects (complete metamorphosis)	Hemimetabolous insects (incomplete metamorphosis)
Developmental stages	Egg–larva–pupa–adult (imago)	Egg–nymph–adult (imago)
Immature stages	Larvae generally differ substantially in morphology from adults	Nymphs generally resemble adults in overall body organization but lack fully developed adult characteristics
Pupal stage	Present; associated with major developmental reorganization	Absent
Wing development	Wing primordia develop internally during immature stages; adult wing structures differentiate and become externally apparent during later development and adult emergence	Wing development is generally external, with visible wing pads developing and enlarging through successive nymphal stages
Representative insects	Butterflies, moths, flies, mosquitoes, bees, ladybirds, and beetles	Grasshoppers, cockroaches, crickets, dragonflies, and many true bugs
Analytical criteria	Correct identification of larval and pupal stages, developmental sequence, and representative organisms	Correct identification of nymphal stages, absence of a pupal stage, developmental sequence, and representative organisms

Data Analysis

Data were analyzed through qualitative content analysis supported by descriptive frequency calculations to characterize the distribution of conceptual errors and instructional inconsistencies. The coding framework incorporated five conceptual error categories adapted from Hershey (2004): misidentification (MI), oversimplification (OS), overgeneralization (OG), undergeneralization (UG),

and obsolete concepts or terminology (OC). These categories were selected because they distinguish different forms of scientific inaccuracy and can be operationalized for evaluating biological explanations in primary-level instructional materials. Two supplementary categories were incorporated to address analytical dimensions not explicitly captured by the original framework: internal contradiction (IC) and assessment misalignment (AM). The IC category was informed by representational coherence principles and was applied when two or more related textbook components communicated mutually incompatible scientific information. The AM category was informed by instructional alignment principles and was applied when assessment content contradicted the instructional explanation, reproduced a conceptual error, or failed to provide a scientifically defensible basis for the intended response. Scientifically inaccurate assessment items were distinguished from content misalignment by examining whether the problem involved an incorrect biological claim, a discrepancy between the question and instructional content, or both. Editorial deficiencies, including typographical errors and missing source information, were documented separately unless they directly altered scientific meaning. Each coded instance was assigned a primary category corresponding to its principal analytical deficiency, while secondary codes could be recorded when an instance exhibited additional conceptual or representational problems. Frequencies represented documented coded instances rather than necessarily unique underlying misconceptions or independent biological errors, and the findings were interpreted descriptively without attributing causal effects to students' learning.

Table 2. Operational categories and coding decision rules

Code	Category	Operational definition	Primary coding decision rule
MI	Misidentification	Incorrect identification, classification, or definition of a biological concept, organism, or developmental stage	Assigned when the principal error involves incorrect biological identification or classification
OS	Oversimplification	An explanation omits essential scientific conditions, producing an inaccurate or misleading representation	Assigned when excessive simplification changes the scientific meaning
OG	Overgeneralization	A biological concept or developmental characteristic is applied beyond its scientifically valid scope	Assigned when the principal problem involves an unjustified extension of a concept
UG	Undergeneralization	A concept is described too narrowly, excluding scientifically valid cases or conditions	Assigned when the principal problem involves an unjustified restriction of a concept
OC	Obsolete concepts and terminology	Scientific terminology or explanations no longer accepted in contemporary biological knowledge	Assigned when the principal error concerns outdated scientific concepts or terms
IC	Internal contradiction	Two or more related statements or representations within the chapter communicate incompatible scientific information	Assigned when the contradiction between components is the principal analytical problem
AM	Assessment misalignment	An assessment item reproduces a conceptual error, contradicts instructional content, or contains a scientifically ambiguous or indefensible intended answer	Assigned when the principal problem concerns the assessment item's conceptual accuracy or alignment

Research Procedure

The analytical procedure was organized into five stages adapted from Krippendorff's (2018) content analysis framework: unitizing, recording and coding, reducing, inferring, and narrating. During unitizing, the selected chapter was systematically examined, and relevant textual propositions, visual representations, and assessment items were segmented and assigned location

identifiers based on page numbers and unit sequences. The complete analytical corpus comprised [information required: total number of textual, visual, and assessment units examined], while sentences containing multiple independently assessable scientific claims were divided into separate analytical units. During recording and coding, each unit was compared with established entomological references, and discrepancies were classified according to the operational definitions and decision rules presented in Table 2. Where multiple categories were applicable, the principal scientific or instructional deficiency determined the primary code, while additional characteristics were documented as secondary codes to preserve analytical information without automatically duplicating the frequency count. During reducing, similar findings were organized by instructional component and primary error category, and their frequencies were calculated as coded occurrences rather than assumed unique conceptual errors. During inferring, the analysis examined the scientific and instructional implications of the identified discrepancies, particularly whether inaccurate explanations were repeated or contradicted across textual, visual, and assessment components, without making claims about demonstrated effects on learners. During narrating, representative textbook excerpts were presented alongside English translations, scientific explanations, and proposed corrections, with translation equivalence requiring verification against the original Indonesian terminology. To strengthen credibility and confirmability, identified conceptual inaccuracies were cross-checked against Gullan and Cranston (2014) and Truman and Riddiford (1999), while peer debriefing was used to critically examine the interpretation of selected findings. The dependability of the analysis requires a documented coding record, including coding decisions, revisions, and the resolution of interpretive disagreements; the specific audit procedures and peer-review details must be reported according to the records available from the completed study.

Trustworthiness and Analytical Rigor

The trustworthiness of the analysis was considered in relation to credibility, confirmability, and dependability, following Lincoln and Guba (1985). Credibility was supported through comparison of identified inaccuracies with established entomological references and consideration of alternative interpretations of biological terminology and developmental processes. Confirmability was addressed by linking each coded finding to its original textbook location, documented evidence, scientific reference, and proposed correction. Peer debriefing was used to critically examine the interpretation of findings, although the expertise of the reviewers, the extent of their involvement, and any resulting coding revisions require explicit documentation. Dependability was considered through the use of operational definitions and consistent coding decision rules across textual, visual, and assessment units. Because the original analysis did not establish independent coding by multiple researchers, intercoder reliability was not calculated, and no claim of independently verified coding agreement was made. A documented coding audit, including records of category assignments, interpretive uncertainties, and subsequent revisions, would strengthen the transparency and reproducibility of the analytical process. Where entomological references differed in terminology or explanatory emphasis, interpretations should be evaluated against the biological context and the specific claim presented in the textbook. English translations of representative Indonesian excerpts should also be checked for terminological and conceptual equivalence before publication. These procedures provide a basis for evaluating analytical transparency while acknowledging the methodological limitations associated with a single-coder document analysis.

RESULTS AND DISCUSSION

Results

Distribution of Conceptual Errors and Instructional Inconsistencies

The content analysis of Chapter 2 identified 33 documented findings involving conceptual errors, cross-representational inconsistencies, and assessment-related deficiencies. These findings comprised 18 occurrences in textual explanations (54.5%), six in visual materials (18.2%), and nine in assessment items (27.3%). The frequencies represent documented occurrences within the analyzed chapter rather than 33 necessarily independent biological errors, because related inaccuracies sometimes appeared in different instructional components. Misidentification (MI) was the most frequently assigned primary category, accounting for 13 findings (39.4%), followed by assessment misalignment (AM) with 11 findings (33.3%), internal contradiction (IC) with five findings (15.2%), oversimplification (OS) with three findings (9.1%), and undergeneralization (UG) with one finding (3.0%). The overgeneralization (OG) and obsolete concepts and terminology (OC) categories were not assigned as primary codes. Within textual explanations, misidentification accounted for 12 of 18 findings (66.7%), indicating that incorrect biological identification, classification, and terminology were the most frequently documented textual problems. Among visual findings, internal contradiction accounted for three of six occurrences (50.0%), while assessment-related findings were initially grouped under assessment misalignment. However, some assessment findings concerned editorial organization rather than scientific accuracy, requiring careful differentiation during interpretation. The distribution of findings is presented in Table 3.

Table 3. Distribution of documented conceptual errors, representational inconsistencies, and assessment-related findings

Category	Text	Visual	Assessment	Total	Percentage (%)
MI – Misidentification	12	1	0	13	39.4
OS – Oversimplification	3	0	0	3	9.1
OG – Overgeneralization	0	0	0	0	0.0
UG – Undergeneralization	1	0	0	1	3.0
OC – Obsolete concepts and terminology	0	0	0	0	0.0
IC – Internal contradiction	2	3	0	5	15.2
AM – Assessment misalignment	0	2	9	11	33.3
Total	**18**	**6**	**9**	**33**	**100.0**

The distribution demonstrates that the identified problems were not confined to isolated scientific statements but occurred across multiple instructional components. Textual findings primarily involved incorrect biological classifications and explanations, whereas visual findings frequently concerned inconsistencies between diagrams and accompanying descriptions. Assessment-related findings included questions that reproduced inaccurate concepts, contradicted instructional explanations, or presented organizational deficiencies. These differences indicate that the identified problems varied in both their scientific characteristics and instructional functions. Accordingly, the numerical distribution should not be interpreted as evidence that one component necessarily produces greater learning difficulties than another. Rather, the frequencies describe the types and locations of inaccuracies documented within the selected chapter.

Finding T1 illustrates the use of overlapping analytical categories. The inclusion of frogs among examples of complete insect metamorphosis was assigned misidentification as the primary code because the principal error concerned the incorrect application of a biological classification. An overgeneralization element was also identified because the classification of insect holometaboly was extended to an amphibian. The secondary category was retained to describe this additional conceptual characteristic without increasing the frequency count. This distinction allowed the

analysis to recognize overlapping conceptual problems while maintaining a consistent primary coding structure.

Conceptual Errors in Textual Explanations

The textual analysis identified 18 findings involving misidentification, oversimplification, undergeneralization, and internal contradiction. These inaccuracies concerned organism classification, developmental stages, reproductive processes, biological terminology, and the distinction between complete and incomplete metamorphosis. Several findings involved incorrect identification of organisms or developmental structures, whereas others reflected explanations that omitted essential biological distinctions. Internal contradictions were also identified when statements within the same instructional section communicated incompatible information. Table 4 presents the documented textual findings and their scientifically appropriate corrections.

Table 4. Conceptual errors and internal contradictions identified in textual explanations

Code	Page	Statement or problem identified	Category	Scientifically appropriate explanation
T1	25	Frogs are presented as examples of complete metamorphosis alongside holometabolous insects.	MI (+OG)	Frogs undergo amphibian metamorphosis involving developmental transformation from tadpole to adult, but they do not undergo insect holometaboly involving a pupal stage.
T2	26	Ladybirds are classified as undergoing incomplete metamorphosis.	MI	Ladybirds (Coccinellidae) are holometabolous insects with egg, larval, pupal, and adult stages.
T3	37	Dragonflies appear under the heading “complete metamorphosis,” although the paragraph describes incomplete metamorphosis.	IC	Dragonflies undergo hemimetabolous development without a pupal stage.
T4	35	Fertilisation is described as occurring in male animals.	MI	In insects exhibiting internal fertilisation, sperm transferred by the male fertilises eggs within the female reproductive system; reproductive mechanisms vary among animal groups.
T5	35	Egg-cell division is described as producing numerous eggs.	MI	Cleavage involves embryonic cell divisions following fertilisation and does not determine the number of eggs produced by the female.
T6	35	The pupal stage is described primarily as transformation into a larger animal.	MI	The pupal stage involves developmental reorganization and differentiation of adult structures rather than merely an increase in body size.
T7	35	A cocoon is equated with an exoskeleton.	MI	A cocoon is a protective structure, commonly composed of silk, whereas an insect exoskeleton consists primarily of the external cuticle.
T8	35	The pupa is described as undergoing “metabolism formation.”	MI	The expression does not accurately identify the developmental processes occurring during pupation, which include tissue remodeling and differentiation of adult structures.

T9	35	Only some insect larvae are described as developing an exoskeleton.	UG	Insect larvae possess an external cuticle from hatching, which is renewed through moulting during development.
T10	37	Fly metamorphosis is described as having four phases, but only three are named.	IC	Complete metamorphosis in flies includes egg, larva, pupa, and adult stages.
T11	26	Hemimetabolous insects are described as repeatedly moulting their skin and wings.	MI	The cuticle is shed during moulting, while developing wing pads enlarge through successive immature stages rather than being replaced as separate wings.
T12	36	The adult stage is described as becoming accustomed to avoiding predators.	MI	Predator avoidance is not a defining characteristic of the imago and should not be presented as the biological purpose of adult development.
T13	25	Cocoon and chrysalis are treated as equivalent biological structures.	MI	A cocoon is an external protective covering produced by certain insects, whereas a chrysalis is the pupal stage of a butterfly.
T14	26	The term larva is used for the immature stage of hemimetabolous insects.	MI	The immature stage of hemimetabolous insects is generally termed a nymph, with naiad commonly used for aquatic immature forms in some groups.
T15	36	Hemimetabola and Paurometabola are used interchangeably without explanation.	OS	Paurometaboly is commonly used for gradual development involving nymphs that resemble adults, whereas hemimetaboly is used more broadly or differently depending on the entomological classification adopted.
T16	36–37	Complete and incomplete metamorphosis are distinguished primarily by counting developmental stages.	OS	The distinction should emphasize the presence or absence of a pupal stage and the developmental organization of immature and adult forms.
T17	37	The early developmental stages of mosquitoes are described as occurring exclusively on the water surface.	OS	Mosquito eggs, larvae, and pupae have different relationships with aquatic habitats, and egg-laying locations vary among species.
T18	24	Monitor lizards are grouped with amphibians.	MI	Monitor lizards (*Varanus* spp.) are reptiles rather than amphibians.

Biological Misclassification of Metamorphosis Patterns

Findings T1 and T2 were particularly relevant to the central instructional topic because they involved incorrect classification of organisms according to metamorphosis patterns. Both findings concerned the biological distinction between complete and incomplete metamorphosis, which formed the conceptual basis of the chapter. T1 involved extending the classification of insect holometaboly to an amphibian, whereas T2 involved incorrectly assigning a holometabolous insect to incomplete metamorphosis. These examples were selected for detailed interpretation because they directly affected the accuracy of the textbook's principal biological classification.

Excerpt 1. Finding T1 (p. 25)

Ciri-ciri hewan yang mengalami metamorfosis sempurna adalah: […] Mengalami masa kepompong atau pupa […].

Contoh hewan yang mengalami metamorfosis sempurna adalah: Nyamuk, Lalat, Kupu-kupu, Katak, Lebah.
[The characteristics of animals undergoing complete metamorphosis include passing through a cocoon or pupal stage. Examples include mosquitoes, flies, butterflies, frogs, and bees.]

Excerpt 1 demonstrates an inconsistency between the textbook's stated classification criterion and the organisms presented as examples. The explanation identifies the pupal stage as a defining characteristic of complete metamorphosis but subsequently includes frogs among the representative organisms. Although frogs undergo substantial morphological and physiological transformations during development, amphibian metamorphosis differs from insect holometaboly. The transition from tadpole to adult frog does not involve a pupal stage, making frogs inappropriate examples of complete insect metamorphosis. The problem therefore concerns the application of an insect-specific developmental classification to an organism belonging to a different animal group. This distinction is scientifically important because metamorphosis is a broader biological phenomenon, whereas holometaboly and hemimetaboly describe particular developmental patterns in insects. The textbook's presentation does not adequately distinguish these levels of biological explanation. Consequently, the inconsistency creates potential ambiguity concerning the criteria used to classify developmental processes, although its actual interpretation by learners was not investigated.

Finding T2 presents a different form of classification error because ladybirds are insects but are assigned to the incorrect developmental category. Ladybirds belong to the family Coccinellidae within Coleoptera and undergo holometabolous development involving egg, larval, pupal, and adult stages (Gullan & Cranston, 2014). Their classification as insects undergoing incomplete metamorphosis therefore contradicts established entomological knowledge. Unlike T1, which extends a developmental category beyond its appropriate biological context, T2 incorrectly classifies an organism within the insect group itself. Together, these findings demonstrate that the textbook contains inaccuracies concerning both the scope and application of metamorphosis classifications. Such errors are particularly relevant to textbook evaluation because the accuracy of representative examples is necessary for maintaining consistency between scientific definitions and their applications.

Previous research has examined conceptual difficulties associated with insect life cycles and developmental classifications. Cinici (2013), for example, investigated students' understanding of insect life stages, providing evidence that the interpretation of developmental transformations can be challenging in science learning. However, the present study differs methodologically because it examines documentary inaccuracies rather than students' conceptual responses. The conceptual relationship between these investigations lies in their shared attention to the accurate differentiation of insect developmental stages. Accordingly, the present findings contribute evidence concerning the scientific quality of instructional explanations without establishing whether the documented inaccuracies produce corresponding misconceptions among learners.

Inaccuracies in Reproductive and Developmental Processes

Findings T4 and T5 were selected for further examination because they involved foundational biological processes underlying insect development. Both inaccuracies occurred within a short passage explaining reproduction and the formation of developmental stages. Their proximity within the same explanation illustrates how multiple conceptual problems can coexist within a single instructional context.

Excerpt 2. Findings T4 and T5 (p. 35)
Pada fase ini telur–telur yang dihasilkan oleh betina berasal dari hasil fertilisasi yang terjadi pada hewan berkelamin Jantan. […] Hasil pembelahan sel telur menghasilkan telur yang cukup banyak.

[In this phase, the eggs produced by the female result from fertilisation occurring in male animals. The division of the egg cell produces a relatively large number of eggs.]

Excerpt 2 contains two distinct inaccuracies concerning fertilisation and embryonic cell division. The first statement incorrectly locates fertilisation in male animals, whereas internal fertilisation in the insects relevant to this explanation occurs within the female reproductive system following sperm transfer. In many insects, transferred sperm may be stored in the female reproductive tract before fertilisation occurs during egg passage through the reproductive system (Gullan & Cranston, 2014). This explanation should be understood within the relevant reproductive context rather than generalized to all animal groups, which exhibit different fertilisation mechanisms. The second statement incorrectly describes egg-cell division as the process responsible for producing numerous eggs. Cleavage refers to successive cell divisions during early embryonic development, whereas egg production involves reproductive processes associated with the female reproductive system. Consequently, the passage conflates egg production, fertilisation, and embryogenesis, although these processes are biologically distinguishable. The use of technical terms such as *fertilisasi* and *pembelahan sel* does not resolve this problem because the relationships among the processes are inaccurately represented. These findings demonstrate that scientific terminology must be accompanied by conceptually appropriate explanations to communicate biological processes accurately.

Terminological Inaccuracies and Internal Contradictions

Additional textual findings involved developmental terminology, morphological structures, and inconsistencies within instructional explanations. Findings T7 and T13 concerned the distinction between cocoons, chrysalises, and exoskeletons, which represent different biological structures. A cocoon is generally an external protective covering produced by certain insects, whereas a chrysalis refers to the pupal stage of a butterfly. The exoskeleton, by contrast, is the external supporting and protective cuticular structure of an arthropod. Treating these terms as interchangeable obscures their distinct biological meanings. Finding T14 similarly involved the use of larva for hemimetabolous immature stages, although nymph is generally the appropriate term. This distinction is relevant because larvae and nymphs differ in their developmental organization and relationships to adult morphology.

Finding T15 involved the unexplained use of hemimetaboly and paurometaboly as interchangeable terminology. These terms are related but may be distinguished according to the developmental characteristics and classification systems adopted in entomological literature. Paurometaboly commonly refers to gradual development in which immature forms resemble adults and generally occupy similar environments, whereas hemimetaboly may be used more broadly in descriptions of incomplete insect metamorphosis. Without clarification, the textbook does not adequately explain the relationship between these terms. Finding T16 further simplified the distinction between complete and incomplete metamorphosis by emphasizing the number of developmental stages. Although stage sequences are useful descriptive features, the presence or absence of a pupal stage and the nature of developmental transformation provide more informative biological criteria. Defining metamorphosis primarily through stage counting may therefore limit the conceptual completeness of the explanation, although the present study did not examine whether learners adopted this approach.

Internal contradictions were documented in T3 and T10. In T3, the dragonfly appeared under a heading referring to complete metamorphosis, while the accompanying paragraph correctly described its development as incomplete. In T10, the fly was described as undergoing four developmental phases, although the accompanying sentence explicitly named only three. These findings demonstrate inconsistencies between the organizational structure and explanatory content

of the textbook. Several inaccuracies were located on pages 35–37, particularly in sections addressing developmental processes. However, because the number of analyzed units per page was not established, this concentration cannot be interpreted as evidence that these sections had a higher proportional error rate than other parts of the chapter. The findings instead demonstrate the presence of multiple conceptual and explanatory deficiencies within the documented locations.

Cross-Representational Inconsistencies in Visual Materials

The analyzed chapter contained 15 images, including eight diagrams directly related to insect metamorphosis. The analysis documented six visual findings involving scientific terminology, text–visual contradictions, and instructional alignment. Four of the eight metamorphosis diagrams were reported as consistent with established biological explanations, while four were associated with identified conceptual or representational discrepancies. The remaining visual findings concerned illustrations accompanying assessment items rather than inaccuracies in metamorphosis diagrams. This distinction is important because a visual finding may involve disagreement with accompanying text even when the illustration itself represents the biological process accurately. The analysis therefore considered both the scientific accuracy of individual images and their consistency with related instructional content. Table 5 summarizes the six documented visual findings.

Table 5. Visual inaccuracies and cross-representational inconsistencies

Code	Page	Image	Identified problem	Category
V1	24	Butterfly life cycle showing egg, larva, pupa, and adult stages	The diagram identifies the chrysalis, whereas the accompanying text does not clearly distinguish chrysalis from cocoon.	IC
V2	34	Photograph of maize accompanying a question about fruit production	The photograph does not directly represent the developmental transition requested by the question, and the relevant plant life-cycle explanation is absent.	AM
V3	36	Grasshopper life cycle showing successive nymphal instars	The diagram represents gradual nymphal development, whereas the text simplifies development into three stages and inaccurately describes wing moulting.	IC
V4	37	Dragonfly life-cycle diagram	The aquatic immature stage is labelled larva rather than nymph or naiad, and the diagram appears under a heading referring to complete metamorphosis.	MI
V5	37	Fly life-cycle diagram showing egg, larva, pupa, and adult	The diagram includes the pupal stage omitted from the accompanying textual sequence.	IC
V6	39	Photographs of a snake and crocodile accompanying a life-cycle question	The assessment content is not adequately supported by the preceding instructional explanations.	AM

Contradictions in Dragonfly Life-Cycle Representations

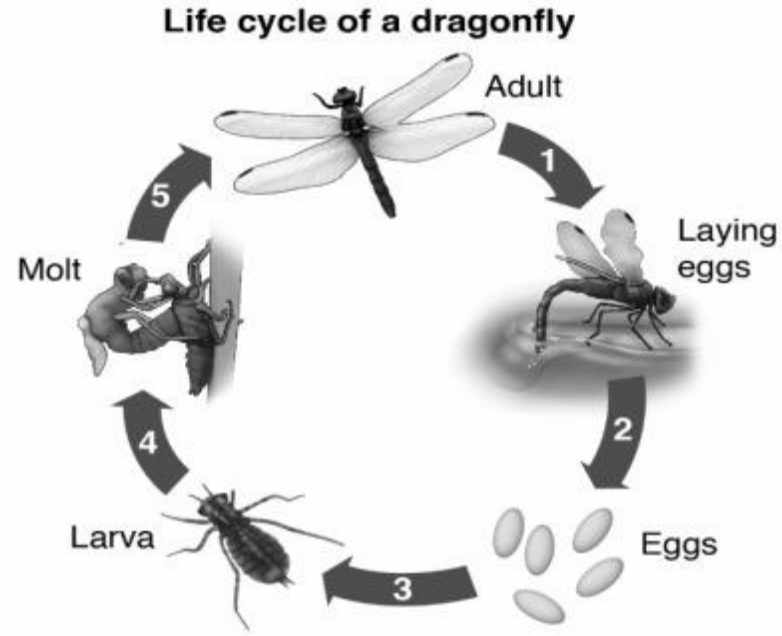


Figure 1. Dragonfly life-cycle diagram in the analyzed textbook (p. 37), presented under the heading for complete metamorphosis.

Excerpt 3. Text accompanying Figure 1 (findings T3 and V4)

Siklus Metamorfosis sempurna terjadi pada hewan:
a. Metamorfosis capung
Mengapa metamorfosis capung dikatakan tidak sempurna? Ternyata hal ini disebabkan oleh karena siklus hidup capung tidak melewati masa pupa atau kepompong.
[Complete metamorphosis occurs in the following animals: a. Dragonfly metamorphosis. Why is dragonfly metamorphosis considered incomplete? This is because its life cycle does not include a pupal or cocoon stage.]

Figure 1 and Excerpt 3 demonstrate three related but analytically distinct inconsistencies involving biological classification, developmental terminology, and representational coherence. First, the heading places dragonflies within complete metamorphosis, although dragonflies undergo hemimetabolous development without a pupal stage. Second, the explanatory paragraph correctly identifies dragonfly metamorphosis as incomplete, directly contradicting the heading. Third, the diagram labels the aquatic immature stage as larva rather than nymph or naiad. In entomological terminology, dragonflies undergo development through aquatic immature stages commonly referred to as naiads, which are specialized nymphal forms (Gullan & Cranston, 2014). The distinction is relevant because larval and nymphal development are associated with different metamorphosis patterns. The diagram also includes labels representing biological processes, such as egg laying and moulting, alongside developmental stages. These elements are not equivalent analytical units because egg laying and moulting describe processes rather than separate developmental stages. Consequently, the diagram's organization may create ambiguity if all labelled elements are interpreted as equivalent stages. Nevertheless, the study did not investigate how students interpreted the diagram, so this ambiguity is identified as a characteristic of the instructional representation rather than an observed learning outcome.

The dragonfly example illustrates a failure of representational coherence within a single instructional section. The heading communicates one developmental classification, the paragraph communicates another, and the diagram introduces inconsistent terminology. Although the

paragraph correctly identifies the absence of a pupal stage, its relationship with the heading and diagram remains unresolved. This inconsistency is particularly relevant to the Design, Functions, Tasks framework, which emphasizes the complementary and constraining functions of multiple representations (Ainsworth, 2006). In the analyzed material, the representations do not consistently constrain interpretation toward the same biological explanation. Instead, they provide conflicting information about the classification and developmental terminology of the same organism. The finding therefore demonstrates how an otherwise scientifically correct statement may coexist with inaccurate or contradictory instructional representations.

Contradictions in Fly Life-Cycle Representations

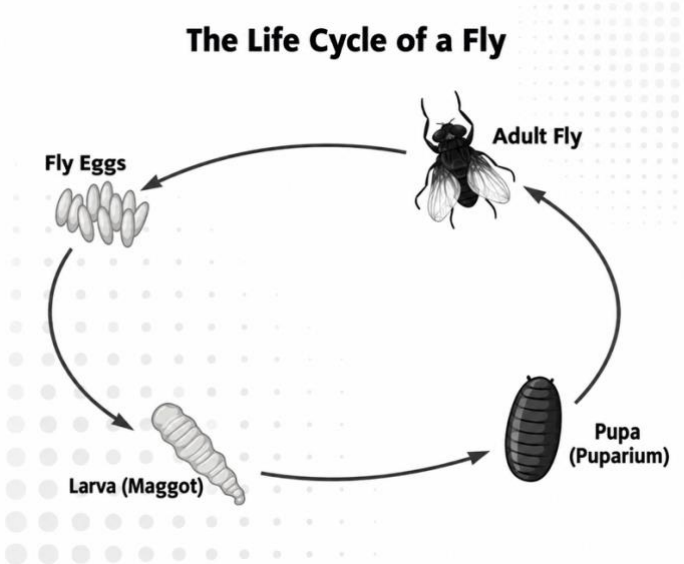


Figure 2. Fly life-cycle diagram in the analyzed textbook (p. 37), showing four developmental stages and a partially visible commercial logo.

Excerpt 4. Text accompanying Figure 2 (findings T10 and V5)

Metamorfosis Lalat memiliki empat fase metamorfosis sempurna yang dialami lalat dimulai dari telur, larva, hingga menjadi lalat dewasa.

[Fly metamorphosis consists of four phases of complete metamorphosis, beginning with the egg and larval stages and continuing to the adult fly.]

Unlike the dragonfly example, the fly diagram presents a scientifically appropriate developmental sequence that is more complete than the accompanying textual explanation. Figure 2 identifies the egg, larval, pupal, and adult stages, consistent with holometabolous development. However, Excerpt 4 states that fly metamorphosis consists of four phases while explicitly naming only three stages. The omission of the pupal stage is significant because pupation constitutes a defining feature of complete metamorphosis. Consequently, the text and diagram do not communicate the developmental sequence with equivalent completeness. The diagram provides information that could complement the text, but the incomplete explanation weakens the coherence between the two representations.

The terminology used in the diagram introduces an additional concern. The pupal stage is labelled *Pupa (Kepompong)*, although the biological structures associated with pupation differ among insect groups. In many cyclorrhaphous flies, the pupa develops within a puparium formed from the hardened cuticle of the final larval instar rather than within a silk cocoon (Gullan & Cranston, 2014). This distinction is relevant to the broader terminological inaccuracies identified in T13. The diagram also contains a partially visible commercial logo without explicit source attribution. However, the available evidence does not establish the original source of the image or the circumstances of its

inclusion in the textbook. Therefore, the missing attribution is reported as an editorial observation rather than evidence of a particular image acquisition practice.

Patterns of Text–Visual Consistency

The visual analysis revealed different relationships between textual and pictorial representations. In V1, V3, and V5, the diagrams contained biologically relevant information that was more accurate or complete than the corresponding textual explanations. In V4, the diagram contained an inaccurate developmental label and appeared under an incorrect classification heading. Four additional metamorphosis diagrams, representing cockroach, cricket, bee, and mosquito development, were reported as consistent with established biological explanations. Accordingly, four of the eight metamorphosis diagrams (50.0%) were not associated with identified scientific or representational discrepancies. Three diagrams (37.5%) were involved in inconsistencies primarily attributable to accompanying textual explanations, while one diagram (12.5%) contained a documented developmental terminology problem. These proportions describe the relationships identified in the analyzed diagrams rather than providing a comprehensive comparison of textual and visual accuracy across all instructional units.

The observed inconsistencies can be interpreted through the specific functions of multiple representations described by Ainsworth (2006). The complementary function is relevant when diagrams provide developmental information that is absent or insufficiently explained in the text, as illustrated by the fly life-cycle representation. The constraining function concerns the capacity of one representation to limit inappropriate interpretations of another. In the dragonfly example, this function is weakened because the heading, explanatory paragraph, and diagram labels communicate inconsistent information. The construction function concerns the integration of representations to support more developed conceptual relationships. Although the present research did not investigate students' representational integration, the identified contradictions demonstrate limitations in the coherence of the information available for such integration. These findings indicate that scientific accuracy should be evaluated not only within individual representations but also through the relationships connecting them.

The analysis also documented observable characteristics of visual presentation. Only one of the 15 images included an explicit source attribution, five of the eight metamorphosis diagrams used English labels, and one diagram contained a partially visible commercial logo. These characteristics were recorded as editorial and presentation-related observations rather than direct evidence of biological inaccuracy. Their relevance concerns the consistency of instructional language, the traceability of visual materials, and the clarity of textbook presentation. However, the study did not examine the original sources of the images or the textbook's editorial production process. Consequently, no conclusions were drawn regarding the provenance of unattributed images or the procedures through which they were incorporated into the textbook.

Assessment Misalignment and Conceptual Accuracy

The assessment analysis documented nine findings involving conceptual inaccuracies, contradictions with instructional explanations, content-alignment deficiencies, and editorial problems. These findings were originally grouped under assessment misalignment because they occurred within the evaluative components of the chapter. However, their characteristics were not identical, and not all findings represented scientific misconceptions. Several items reproduced inaccurate biological explanations, while others contained ambiguous answer options or assessed content insufficiently addressed in the preceding instructional material. Two findings primarily involved editorial organization, including duplicated wording and inconsistent question numbering. These editorial observations were retained in the documentation of assessment quality but were

distinguished from conceptual inaccuracies during interpretation. Table 6 presents the identified assessment findings and their implications.

Table 6. Assessment-related findings in the analyzed textbook

Code	Location	Identified problem	Analytical interpretation
A1	Summative 3 no. 1; Chapter Assessment no. 1	The question concerning exceptions to complete metamorphosis includes both frogs and grasshoppers.	Conceptual ambiguity involving metamorphosis classification.
A2	Summative 3 no. 4	Dragonflies appear in a question about incomplete metamorphosis despite contradictory instructional explanations.	Inconsistency between assessment content and textbook classification.
A3	Summative 3 no. 7; Chapter Assessment no. 3	An answer option repeats the same organism.	Editorial deficiency affecting answer-option quality.
A4	Summative 3 no. 8; Chapter Assessment no. 4	The item confuses termite developmental stages with functional castes and uses inappropriate chemical terminology.	Biological inaccuracy accompanied by a separate safety-related concern.
A5	Summative 3 no. 9	The imago is characterized primarily by predator avoidance.	Reproduction of an inaccurate developmental explanation.
A6	Matching no. 16	Metamorphosing animals are equated exclusively with insects.	Conceptual inconsistency with the textbook's inclusion of amphibian metamorphosis.
A7	Matching no. 17	The pupal stage is associated with food gathering.	Biological inaccuracy concerning pupal characteristics.
A8	Summative 1 and 2	Questions address organisms and developmental processes not adequately explained in the preceding instructional content.	Content-alignment deficiency.
A9	Summative 1	Question numbering is inconsistent, and some item numbers are repeated.	Editorial deficiency affecting assessment organization.

Ambiguity in Metamorphosis Classification Assessment

Excerpt 5. Finding A1 (Summative 3 no. 1, p. 38; repeated as Chapter Assessment no. 1, p. 40)

Hewan yang mengalami metamorfosis sempurna, kecuali ….

a. Kupu-kupu
b. Katak
c. Lalat
d. Belalang

[Animals that undergo complete metamorphosis, except: (a) butterfly, (b) frog, (c) fly, and (d) grasshopper.]

Excerpt 5 demonstrates an assessment ambiguity arising from the relationship between the textbook's classification and accepted biological knowledge. Within the classification of insect metamorphosis, butterflies and flies undergo holometabolous development, whereas grasshoppers undergo hemimetabolous development. Frogs undergo amphibian metamorphosis and therefore do not belong to either insect developmental category. Consequently, both frogs and grasshoppers can be excluded from the category of holometabolous insects, although for different biological reasons. The textbook's earlier inclusion of frogs among examples of complete metamorphosis suggests that grasshopper may have been the intended answer. However, the official answer key was not available in the reported evidence, so this interpretation remains conditional. The principal assessment problem is therefore the absence of a uniquely defensible answer when the question is interpreted

using scientifically precise classification criteria. The repetition of the same item in the chapter-level assessment reproduces this ambiguity in another evaluative context. This finding demonstrates how inaccurate classifications within instructional explanations may also appear in assessment content without establishing whether students were actually scored incorrectly.

Biological Inaccuracies and Safety-Related Concerns in Assessment Content

Excerpt 6. Finding A4 (Summative 3 no. 8, p. 38; repeated as Chapter Assessment no. 4, p. 40)

Salah satu tahapan dalam daur hidup laron yang dapat merugikan pengrajin kayu karena memakan kayu, sehingga menyebabkan kayu keropos. Tahapan dalam daur hidup laron yang merusak kayu dan cara yang tepat untuk membasminya adalah ….

a. Nimfa, dengan cara mengolesi kayu dengan herbisida kimia berdosis tinggi.
b. Nimfa, dengan cara menempatkan kayu di ruang yang cukup dengan panas matahari.
c. Imago, dengan cara mengolesi kayu dengan herbisida yang berdosis tinggi.
d. Imago, dengan cara menempatkan kayu di ruang yang cukup dengan panas matahari.

[One stage in the life cycle of flying termites can damage wood by feeding on it. Which developmental stage causes the damage, and which method is appropriate for controlling it?]

Excerpt 6 contains several distinct problems involving termite biology, chemical terminology, and instructional appropriateness. First, the question associates wood consumption with developmental stages of flying termites, although wood damage in termite colonies is more appropriately explained through feeding behavior and the activities of worker termites. Developmental stage and functional caste represent different biological dimensions, making their interchangeable use scientifically inaccurate. Second, the item uses the term herbicide for controlling termites, although herbicides are intended for controlling unwanted plants rather than insects. This terminology introduces an additional conceptual error unrelated to metamorphosis classification. Third, two answer options refer to the application of high-dose chemicals, introducing a safety-related concern within primary-level instructional content. The inclusion of such options is problematic because the item does not provide an appropriate context for evaluating chemical hazards or safe pest-management practices. This concern should be distinguished from the biological inaccuracies because it involves the suitability of instructional content rather than the classification of developmental stages. Taken together, these deficiencies prevent the question from providing a clearly justified scientific answer. The repetition of the item in the chapter-level assessment reproduces the same problems across two assessment locations.

Relationships Between Instructional Content and Assessment Items

The assessment findings demonstrate that inaccuracies may occur through several relationships between instructional explanations and evaluative questions. Items A1, A5, and A6 reproduce or reflect conceptual problems already identified in the textual content. Item A2 illustrates inconsistency between an assessment question and contradictory explanations presented elsewhere in the chapter. Items A4 and A7 contain biological inaccuracies concerning termite behavior and pupal characteristics, while A8 concerns insufficient alignment between assessment content and preceding explanations. These findings indicate that assessment quality requires consideration of both scientific correctness and consistency with instructional content. A question may reproduce an inaccurate textbook explanation while remaining inconsistent with established biological knowledge. Conversely, a scientifically correct question may conflict with an inaccurate instructional statement. Therefore, assessment alignment should not be evaluated solely through agreement with the textbook's explanations but should also involve independent scientific verification.

The repetition of assessment items represents another documented characteristic of the chapter. In particular, A1 and A4 appeared in both subchapter and chapter-level summative assessments. These repeated items retained the same conceptual ambiguities or biological

inaccuracies across different assessment locations. However, repetition within a document does not establish that learners developed corresponding misconceptions or experienced measurable learning difficulties. The findings support the narrower conclusion that inaccurate or ambiguous information was presented repeatedly in the assessment materials. Similarly, the editorial problems identified in A3 and A9 concern assessment organization rather than scientific understanding. Distinguishing these deficiencies prevents the interpretation of all assessment problems as conceptual errors.

Integrated Discussion and Implications for Textbook Improvement

The findings demonstrate that scientific inaccuracies and instructional inconsistencies occurred across textual explanations, visual representations, and assessment items within the selected supplementary science textbook. Misidentification was the most frequently documented conceptual error, particularly in explanations concerning organism classification and developmental terminology. Cross-representational analysis further showed that some diagrams provided scientifically appropriate information while accompanying explanations remained incomplete or contradictory. In other instances, inaccurate terminology and incorrect classification headings occurred alongside visual representations of the same biological process. Assessment analysis revealed that several inaccuracies were reproduced or contradicted in evaluative questions. These relationships demonstrate that textbook quality cannot be adequately evaluated through isolated examination of factual statements alone. Instead, the scientific accuracy and coherence of interconnected instructional components require systematic consideration.

The findings can be interpreted in relation to multimedia learning theory and the Design, Functions, Tasks framework. Mayer (2020) emphasizes that meaningful learning from verbal and pictorial materials depends on the appropriate selection, organization, and integration of relevant information. Ainsworth (2006) similarly explains that multiple representations can complement information, constrain interpretation, and support the construction of conceptual relationships. The documented contradictions indicate that these functions may be weakened when related instructional components communicate incompatible scientific information. For example, the fly diagram contains a complete developmental sequence, but the accompanying explanation omits the pupal stage. The dragonfly example presents a more complex inconsistency because the heading, paragraph, and diagram do not communicate the same classification and terminology. These findings extend the application of representational coherence perspectives to the evaluation of textbook inaccuracies. Nevertheless, the analysis does not demonstrate how learners process these contradictions or whether they produce measurable misconceptions. Its contribution lies in identifying scientifically problematic relationships within the instructional materials themselves.

The results also highlight the importance of distinguishing conceptual accuracy from editorial quality. Incorrect metamorphosis classifications, inaccurate descriptions of reproductive processes, and inappropriate developmental terminology represent scientific content problems. Contradictions between diagrams and explanatory text represent deficiencies in representational coherence. Ambiguous answer options and assessment questions with scientifically indefensible answers concern assessment accuracy and alignment. Missing image attribution, duplicated answer options, and inconsistent numbering represent editorial or presentation-related deficiencies. Although these dimensions may coexist within the same textbook, they should not automatically be treated as equivalent forms of conceptual error. Maintaining these distinctions supports a more precise interpretation of the documented findings and provides clearer directions for textbook improvement.

Several targeted revisions follow directly from the identified findings. First, the textbook should distinguish insect holometaboly and hemimetaboly from amphibian metamorphosis and

correct the classification of representative organisms, particularly frogs and ladybirds. Second, explanations should consistently differentiate larvae, nymphs, pupae, cocoons, chrysalises, and related developmental structures. Third, biological processes involving fertilisation, embryogenesis, moulting, and pupal transformation should be revised using scientifically appropriate terminology. Fourth, life-cycle diagrams should be harmonized with accompanying headings, captions, and explanatory paragraphs to eliminate contradictory representations. Fifth, assessment items should be reviewed to ensure scientifically defensible answers, conceptual clarity, and alignment with validated instructional content. Editorial improvements should additionally address duplicated answer options, inconsistent numbering, unexplained English labels, and missing image attribution. These recommendations are directly connected to the documented deficiencies and do not require assumptions about the textbook's production history.

The findings are also relevant to the content and presentation dimensions of Ministerial Regulation No. 22 of 2022. Scientifically inaccurate classifications and explanations concern the accuracy of instructional content, while inconsistent headings, diagrams, and captions relate to the coherence of textbook presentation. Assessment items containing ambiguous or biologically inaccurate answers similarly warrant evaluation as part of instructional quality assurance. However, determining formal compliance with the regulation would require a separate assessment against its specific provisions and indicators. Accordingly, the present findings provide evidence supporting targeted textbook revision rather than a comprehensive regulatory judgment.

Several limitations should be considered when interpreting the results. First, the investigation was restricted to one chapter of one supplementary IPAS textbook, limiting the transferability of the findings to other educational materials. Second, the reported frequencies represent documented occurrences rather than estimates of the prevalence of conceptual errors across textbooks. Third, the analysis did not include student interviews, classroom observations, or learning assessments, preventing conclusions about the actual effects of the identified inaccuracies on students' conceptual understanding. Fourth, the available evidence did not establish the textbook's editorial review procedures or the provenance of its visual materials. Future studies could extend the analysis to multiple supplementary textbooks and examine how teachers and learners interpret inconsistent biological explanations and representations. Such investigations would complement document-based evidence and provide a stronger empirical foundation for understanding the relationship between textbook accuracy and science learning.

Discussion

The findings of this study demonstrate that conceptual inaccuracies remain an important concern in primary science instructional materials, particularly when biological classifications and developmental processes are presented without sufficient scientific precision. Among the 33 documented findings, misidentification constituted the largest category (39.4%), indicating that incorrect organism classification, developmental terminology, and biological identification were prominent characteristics of the analyzed chapter. This pattern is consistent with previous investigations identifying misidentification, oversimplification, and other conceptual inaccuracies in biology-related textbook content. Similarly, recent research on Indonesian biology textbooks has documented conceptual inaccuracies across different biological topics and educational levels, demonstrating the continuing relevance of systematic textbook evaluation (Vydra & Kováčik, 2025). However, the distribution of conceptual errors may vary according to the biological topic, textbook characteristics, and operational definitions used during analysis (Li et al., 2020; Pacaci et al., 2024; Parthasarathy, 2023). The incorrect classification of frogs and ladybirds illustrates how inaccurate examples can undermine the correspondence between biological definitions and the organisms used to explain them. Previous research has also reported difficulties in students' understanding of insect

developmental stages and metamorphosis classifications, indicating that these concepts require careful instructional explanation. Nevertheless, findings from student-conception studies should be distinguished from textbook analyses because the former examine learners' understanding, whereas the latter evaluate the scientific accuracy of instructional materials. Consequently, the present findings cannot establish whether the identified textbook errors influenced students' conceptual understanding because no learner-response data were collected. The findings therefore extend previous textbook evaluations by demonstrating how inaccuracies in organism classification and developmental terminology coexist within primary-level explanations of insect metamorphosis.

The analysis further revealed that oversimplified explanations and inappropriate biological terminology can compromise the scientific coherence of instructional content when essential conceptual distinctions are omitted. Findings concerning fertilisation, embryonic cleavage, pupal development, and the distinction between larvae and nymphs demonstrate that simplified explanations may become scientifically inaccurate when important biological relationships are incorrectly described. Previous studies of biology textbooks have similarly identified oversimplification, misidentification, and incomplete conceptual explanations as recurring problems in scientific instructional content (Atchia & Gunowa, 2025; Bonilla & Quesada, 2024). Recent investigations of Indonesian biology textbooks have also reported variations in the completeness and accuracy of explanations concerning biological processes, including cell division and developmental mechanisms. Although cell division and insect metamorphosis involve different biological processes, both require explanations that distinguish developmental events, biological structures, and relationships among successive stages. The present findings are particularly relevant because the textbook conflated egg production with embryonic cleavage and described pupation primarily as an increase in organism size rather than developmental reorganization. These inaccuracies indicate that scientific precision cannot be evaluated solely through the simplicity or familiarity of the vocabulary used in instructional explanations. The distinction between a cocoon and a chrysalis provides another example, as treating different biological structures as equivalent obscures scientifically meaningful differences among insect developmental patterns. Nevertheless, the present analysis cannot establish whether these inaccuracies resulted from deliberate simplification, translation practices, or other editorial decisions because the textbook development process was not investigated. Accordingly, the findings emphasize the importance of scientifically accurate explanations that remain accessible to primary learners without eliminating essential biological distinctions.

Cross-representational analysis demonstrated that conceptual accuracy cannot be adequately assessed by examining textual explanations and biological illustrations as independent instructional components. Of the eight insect-metamorphosis diagrams examined, four were associated with documented conceptual or representational discrepancies, including contradictions between developmental sequences, classification headings, and explanatory terminology. In several instances, the diagrams communicated biologically appropriate information while the accompanying text contained omissions or inaccuracies, as illustrated by the fly life-cycle representation. Conversely, the dragonfly example combined an incorrect classification heading with inconsistent developmental terminology, demonstrating how multiple representations can communicate incompatible information about the same biological process. These findings can be interpreted through contemporary multimedia learning theory, which emphasizes the importance of integrating verbal and pictorial information to support coherent conceptual representations (Mayer, 2020). The complementary function of multiple representations was evident when diagrams supplied developmental information omitted from textual descriptions, although such complementarity remained incomplete when the discrepancy was not explicitly resolved. The constraining function was weakened when headings and visual labels failed to support a consistent interpretation of the

biological phenomenon, particularly in the dragonfly example. Recent research on science textbooks has also highlighted the importance of scientific accuracy, visual coherence, and consistency between explanatory statements and instructional representations (Park et al., 2025; Pedrera et al., 2025; Tang, 2023a, 2023b). However, the present study provides a more specific account of how representational discrepancies occur within insect-metamorphosis instruction by examining relationships among diagrams, labels, headings, and accompanying explanations. These findings indicate that visual accuracy and text–visual coherence should be treated as complementary dimensions of textbook evaluation, while the actual effects of representational contradictions on learners require separate empirical investigation.

Assessment-related findings revealed that scientific inaccuracies within instructional explanations may also appear in evaluative questions, creating inconsistencies between biological knowledge, textbook content, and expected responses. The assessment analysis documented nine findings, including ambiguous metamorphosis classifications, incorrect developmental descriptions, insufficiently supported assessment content, and editorial deficiencies. The question asking learners to identify an exception to complete metamorphosis illustrates this problem because both frogs and grasshoppers can be excluded from holometabolous insects, although the textbook's inaccurate classification of frogs suggests a different intended interpretation. Previous studies of biology textbooks have emphasized the importance of conceptual accuracy and completeness in instructional explanations, but the relationship between scientific content and assessment alignment also requires systematic consideration (Abate & Mishore, 2024; Kim et al., 2023; Yu et al., 2022). Recent textbook investigations have identified conceptual inaccuracies in biological explanations, providing a relevant basis for examining whether similar inaccuracies are reproduced in assessment materials. The present study adds an assessment-related perspective by demonstrating that conceptual inaccuracies can appear across explanatory and evaluative components within the same chapter. Nevertheless, the repetition of an inaccurate statement in an assessment item does not establish that learners accepted the statement or that their responses were scored incorrectly. The termite-related question further illustrates the importance of distinguishing biological inaccuracies from other instructional concerns because its confusion between developmental stages and functional castes differs from its inappropriate chemical terminology and safety-related content. Similarly, duplicated answer options and inconsistent numbering should be classified as editorial deficiencies rather than scientific misconceptions, even though they remain relevant to assessment quality. These findings suggest that textbook evaluation should incorporate independent verification of assessment accuracy, consistency with instructional explanations, and the clarity of scientifically defensible answers.

Taken together, the findings contribute to the literature on science textbook quality by demonstrating that conceptual errors, cross-representational inconsistencies, and assessment deficiencies may occur as interconnected characteristics of a single instructional chapter. Recent investigations of biology textbooks have established the relevance of systematic content analysis for identifying conceptual inaccuracies across different biological topics and educational contexts. The present study extends this analytical perspective by examining not only the scientific correctness of individual statements but also the consistency of biological information across textual explanations, visual representations, and assessment items. This integrated approach is particularly relevant to insect metamorphosis because accurate explanations of developmental patterns require coordinated descriptions of organism classification, immature stages, pupal development, and morphological transformation. The findings also support the distinction between conceptual errors embedded in educational materials and misconceptions demonstrated by learners, which represent different analytical objects requiring different forms of empirical evidence. From an instructional-material perspective, the documented inaccuracies justify targeted revisions involving scientifically

appropriate organism examples, consistent developmental terminology, coherent life-cycle diagrams, and assessment questions with defensible answers. These recommendations are consistent with contemporary principles of scientific content accuracy, representational coherence, and instructional alignment in educational-material evaluation. The investigation remains limited to one chapter of one supplementary textbook, and its descriptive frequencies cannot be generalized to other textbooks or interpreted as evidence of measured learning consequences. Future research could extend the analysis to multiple primary science textbooks and examine whether identified representational inconsistencies correspond to difficulties observed through student interviews, drawing tasks, or classroom-based assessments. Ultimately, the principal contribution of this study lies in establishing an integrated analytical perspective through which conceptual accuracy, representational coherence, and assessment alignment can be evaluated as interconnected dimensions of primary science textbook quality.

Implications

The findings of this study provide important implications for improving the scientific accuracy, representational coherence, and assessment quality of primary science textbooks. Textbook authors should ensure that biological classifications, developmental terminology, and explanations of insect metamorphosis are scientifically accurate and appropriate for students' cognitive development. Particular attention should be given to distinguishing amphibian metamorphosis from insect holometaboly and clarifying the differences among larvae, nymphs, pupae, cocoons, and chrysalises. Textual explanations and visual representations should be systematically reviewed to eliminate contradictory classifications, inaccurate labels, and incomplete developmental sequences. Assessment items should also undergo scientific verification to ensure conceptual accuracy, alignment with instructional content, and unambiguous answers. Teachers are encouraged to critically evaluate supplementary materials and clarify identified inaccuracies before classroom implementation. Furthermore, textbook developers should incorporate subject-matter expertise into content validation and editorial review. These improvements may strengthen the scientific consistency and instructional quality of supplementary textbooks. However, their effects on students' conceptual understanding require further empirical investigation. Overall, this study highlights the importance of integrating conceptual accuracy, text–visual coherence, and assessment alignment into primary science textbook quality assurance.

Limitations and Suggestions for Future Research

This study has several limitations that should be considered when interpreting its findings. First, the analysis was limited to one chapter of a single Grade III supplementary IPAS textbook, restricting the generalizability of the results. Second, the study focused on conceptual inaccuracies, visual inconsistencies, and assessment deficiencies without investigating their effects on students' understanding. Third, the descriptive frequencies represent documented findings rather than the overall prevalence of errors in primary science textbooks. Furthermore, the textbook development and editorial validation processes were not examined. Future research should involve multiple textbooks from different publishers and educational contexts to identify broader patterns of conceptual inaccuracies. Classroom-based studies incorporating student interviews, diagnostic assessments, and observations are recommended to investigate how learners interpret inaccurate explanations and contradictory representations. Experimental studies could also evaluate whether revised instructional materials improve students' conceptual understanding of insect metamorphosis. Additionally, further investigations should examine the effectiveness of expert validation and integrated textbook review procedures. Overall, future research should combine textbook content analysis with empirical learning evidence to strengthen the development of scientifically accurate and pedagogically appropriate primary science materials.

CONCLUSION

This study identified 33 findings involving conceptual inaccuracies, representational inconsistencies, assessment misalignment, and editorial deficiencies in the insect-metamorphosis content of a Grade III supplementary IPAS textbook, comprising 18 textual, six visual, and nine assessment-related findings. The major inaccuracies included the misclassification of frogs and ladybirds, incorrect explanations of fertilisation and pupal development, and inconsistent terminology describing insect developmental stages. Cross-representational analysis revealed discrepancies between textual explanations and visual materials, particularly in the dragonfly and fly life-cycle sections, while several assessment items reproduced conceptual inaccuracies, presented ambiguous answer options, or demonstrated insufficient alignment with instructional content. These findings indicate potential instructional risks associated with scientifically inaccurate and internally inconsistent materials, although their effects on students' conceptual understanding were not examined. Accordingly, systematic revisions should address all documented findings by correcting biological classifications, standardizing developmental terminology, harmonizing textual and visual representations, and ensuring scientifically defensible assessment questions. A structured validation process involving biology specialists, science education experts, and textbook editors is recommended to strengthen scientific accuracy, representational coherence, and assessment quality. Education offices and schools should also implement systematic content verification, text–visual consistency checks, and assessment reviews aligned with relevant textbook quality standards. Nevertheless, the study was limited to one chapter of a single textbook, restricting the transferability of its findings to other instructional materials and educational contexts. Furthermore, coding by a single researcher without inter-rater reliability assessment introduces potential subjectivity, while the quality of the available printed pages may have affected the evaluation of fine visual details. Future research should employ comparative analyses of multiple textbooks using standardized coding procedures and independent raters, alongside controlled classroom investigations examining the relationship between exposure to specific textbook inaccuracies and students' conceptual understanding. Overall, this study highlights the importance of integrating conceptual accuracy, representational consistency, and assessment alignment into systematic quality assurance procedures to support the development of scientifically reliable primary science instructional materials.

AUTHOR CONTRIBUTIONS STATEMENT

Farah Dwi Agustina Wigati contributed to the conceptualisation, research design, and manuscript preparation. Delfia Ikhlasiah Rahman contributed to data collection and analysis. Nafi Isbadrianingtyas contributed to the interpretation of findings and manuscript review. Zulfin Rochma Mufidah contributed to scientific validation, critical revision, and final approval of the manuscript. All authors reviewed and approved the final version of the manuscript.

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