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SYSTEMATIC REVIEW

Exploring Misconceptions in Biology Learning: A Systematic Literature Review

Explorando las Concepciones Erróneas en el Aprendizaje de la Biología: Una Revisión Sistemática de la Literatura

Rikardus Herak[1], Susriyati Mahanal[2], Siti Zubaidah[2], Vivi Novianti[2]

[1]Department of Biology Education, Faculty of Teacher Training Education, Universitas Katolik Widya Mandira. Kupang, Indonesia.
[2]Department of Biology, Faculty of Mathematics and Natural Sciences, Universitas Negeri Malang. Malang, Indonesia.

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Corresponding Author: Rikardus Herak

ABSTRACT

Introduction: misconceptions in biology education hinder students' understanding and application of scientific concepts. This study systematically reviews existing literature to examine the nature of misconceptions in biology, their types, and their impact on learning.
Method: a systematic literature review was conducted using the Scopus database. From an initial pool of 5823 articles, 30 original studies were selected according to PRISMA inclusion and exclusion criteria.
Results: the review uncovered multiple definitions of "misconception" in biology, all emphasizing incomplete or incorrect conceptual frameworks. Misconceptions ranged across genetics, ecology, and physiology, among other domains. Evidence shows these misconceptions create confusion, impede deep conceptual understanding, and lead to persistent errors when students attempt to apply biological knowledge in novel contexts.
Conclusions: a comprehensive understanding of biology-related misconceptions is essential for designing targeted instructional strategies. By identifying and addressing these misconceptions, educators can foster clearer conceptual frameworks, enhance critical thinking, and promote deeper, more sustainable learning in biology. The findings underscore the importance of integrating corrective feedback and active-learning approaches to reduce conceptual errors and improve overall student outcomes in biology education.

Keywords: Biology Misconceptions; Misconception Exploration; Biology Intervention.

RESUMEN

Introducción: las ideas erróneas en la enseñanza de la biología dificultan la comprensión y aplicación de conceptos científicos. Este estudio revisa sistemáticamente la bibliografía para examinar la naturaleza de esas ideas erróneas, sus tipos y su impacto en el aprendizaje de biología.
Método: se realizó una revisión sistemática en la base de datos Scopus. De 5823 artículos iniciales, se seleccionaron 30 estudios originales siguiendo criterios PRISMA.
Resultados: la revisión identificó diversas definiciones de "idea errónea" en biología, todas basadas en marcos conceptuales incompletos o equivocados. Se documentaron ideas erróneas en áreas como genética, ecología y fisiología. Las evidencias muestran que estas ideas generan confusión, impiden una comprensión conceptual profunda y provocan errores persistentes cuando los estudiantes aplican conocimientos biológicos en contextos nuevos, complejos o abstractos.
Conclusiones: comprender las ideas erróneas relacionadas con la biología es esencial para diseñar estrategias de enseñanza específicas y efectivas. Al identificar y corregir estos conceptos erróneos, docentes e investigadores pueden fomentar marcos conceptuales más claros, estimular el pensamiento crítico y

promover un aprendizaje más profundo, duradero y sostenible. Los hallazgos subrayan la importancia de integrar retroalimentación correctiva, métodos de aprendizaje activo y evaluaciones formativas continuas para reducir errores conceptuales y mejorar los resultados educativos en biología.

Palabras clave: Misconcepciones de Biología; Exploración de Misconcepciones; Intervención Biológica.

INTRODUCTION

Misconceptions in biology learning are a severe concern in various parts of the world, as seen from various studies in Ecuador, America and Hungary.[1,2,3] In-depth analyses of these misconceptions have been conducted in the Netherlands, Morocco and Argentina.[4,5] Relevant studies have also been conducted in Switzerland, Australia, and several Asian countries such as Indonesia, Thailand and India.[6,7,8,9] That shows that misconceptions in biology learning are a global problem requiring educators' and researchers' attention.[10]

Misconceptions in education refer to students' beliefs or understandings that are inconsistent with scientific explanations.[11] In biology learning, misconceptions occur when students have incorrect or inaccurate understandings of certain biological concepts.[12] Misconceptions occur due to personal experiences, misinformation, ineffective teaching, or misunderstandings in linking new concepts to prior knowledge.[8,13] Misconceptions can hinder a deeper understanding of biological concepts.[14] Therefore, it is necessary to explore misconceptions through their types.[15]

Knowing the types of misconceptions related to biology topics is very important so that the learning process can be carried out more effectively and on targe.[12,16] Misconceptions can hinder students' understanding of basic concepts.[15,17] By understanding the types of misconceptions, educators can design better teaching strategies, correct misunderstandings and improve students' understanding of biology topics.[14,16] Identifying misconceptions is the first step in creating a productive learning environment and achieving learning goals.[15,18]

Literature Review

This paper reviews and analyzes scientific literature on various definitions of misconceptions from the perspective of experts and identifies and categorizes various misconceptions commonly experienced by students in biology learning. In addition, it explores the negative impacts caused by misconceptions in the student learning process by examining several related publications to provide a clearer understanding of misconceptions in the context of biology education. Other researchers have conducted similar research. This systematic literature review (SLR) focuses on original articles, narrowing the scope of research on a particular topic or theme. This paper also aims to help educators and researchers have the same understanding of the terms used related to misconceptions

Various misconceptions in biology learning, especially in the material on cell structure, have been shown.[19] Confusion between concepts such as cell wall and cell membrane, protoplasm and cytoplasm, and nucleus, nucleolus, and nucleoid are examples found in this study.[13] In addition, there are misconceptions about vacuoles and vesicles, cristae and cisternae, chromosomes and chromatin and flagella, cilia, fimbria, and pili.[20] Misconceptions also arise between protoplasts and tonoplasts, centrosomes and centrioles, plastids and plastics, peroxisomes, glyoxysomes, and lysosomes. These misunderstandings indicate that complex and interrelated concepts often give rise to misconceptions, which can significantly impact the biology learning process.[21] Studies have also shown that misconceptions in biology learning can hinder understanding basic and complex concepts and the development of scientific thinking.[16,22] For example, misconceptions about cell structure and function, inheritance, evolution, and ecology result in inaccurate understanding and difficulty in understanding the interactions of organisms with their environment.[23]

Misconceptions reflect the mind's efforts to construct explanations for complex phenomena.[12] Research related to misconceptions in biology topics has been conducted in various countries but is still limited to how to identify student or college student misconceptions. For example, [14,22,24] identified misconceptions about biology among college students.[5,17,25,26] examined misconceptions in students. Therefore, a comprehensive examination of the literature on the definition of misconceptions, types of misconceptions and the impact of misconceptions has not been carried out in the form of SLR.

This SLR provides a comprehensive definition and explanation of misconceptions, an idea sourced from experts' opinions and related studies. This paper also explains the misconceptions commonly experienced by students in biology learning and the impacts caused by misconceptions on the student learning process. This SLR is expected to provide a comprehensive picture of misconceptions in biology learning and contribute to improving the quality of biology education through structured findings and practical recommendations. That aims to reduce students' biological conceptual errors and help them achieve better learning outcomes. This paper focuses on reviewing original articles related to misconceptions in biology learning.

METHOD

Research Framework

This study is a Systematic Literature Review (SLR) that utilizes methods to identify, evaluate, and analyze the latest and relevant literature and references to explain the research topic and problem comprehensively.[27] This Systematic Literature Review (SLR) uses a structured and methodical approach, allowing researchers to comprehensively evaluate and synthesize the evidence in the literature.[28] This Systematic Literature Review (SLR) involves developing a careful search strategy, rigorous selection of articles, and critical analysis of relevant findings.[29] Thus, SLR helps ensure that the research results are high-quality and reliable information, strengthening the knowledge base in a particular discipline.[30]

Research Question (RQ)

Research questions are essential in indicating how deep and focused research is. Research questions guide the research steps to be clear and focused. This research question is formulated based on the needs of the chosen topic, namely:

RQ 1: what are the definitions of misconceptions in biology?
RQ 2: what are the types of misconceptions related to biology?
RQ 3: what is the impact of misconceptions on biology learning?

Search Article and Inclusion Criteria

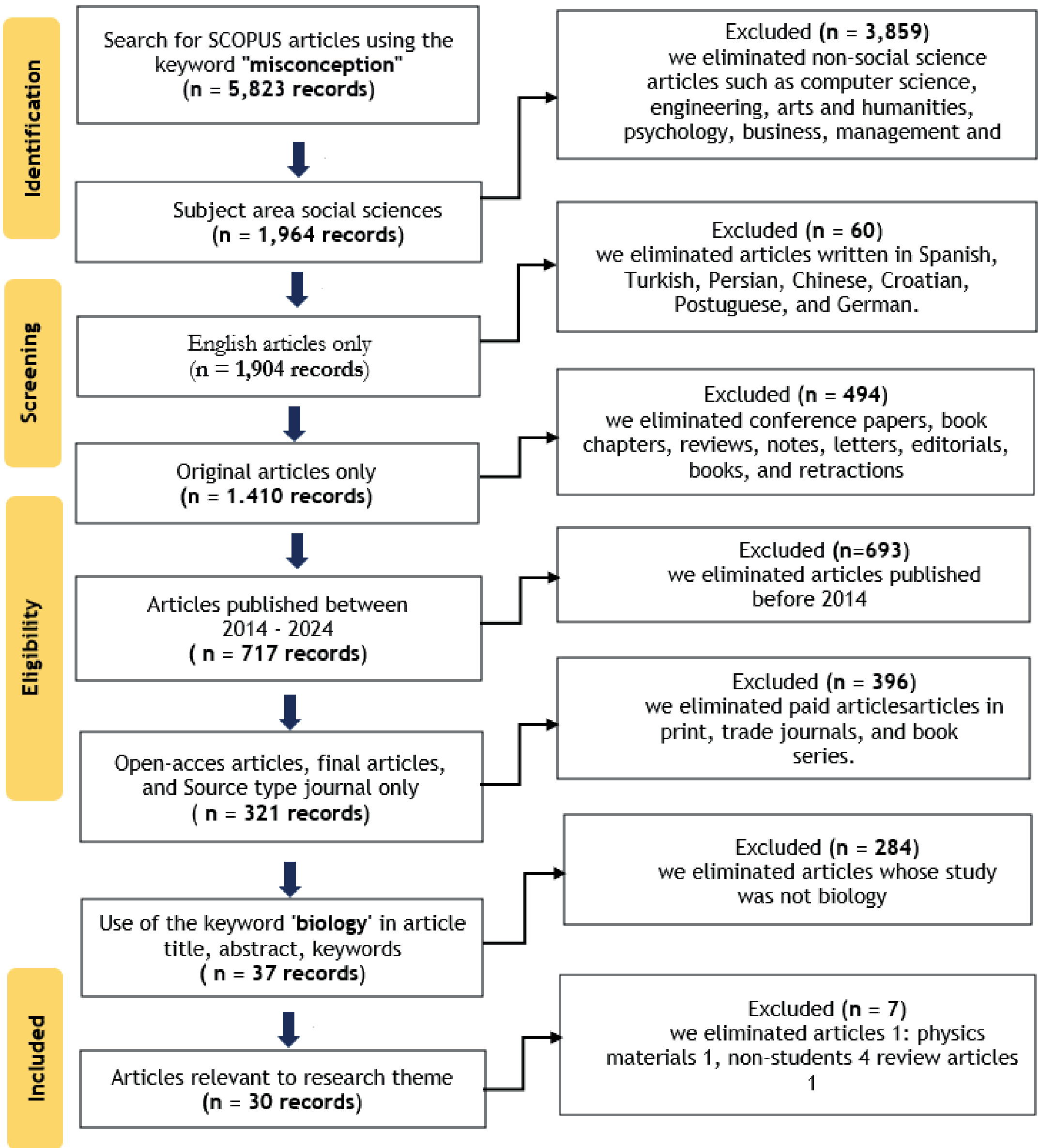

Figure 1. PRISMA diagram

We used the keyword "Misconceptions" when searching articles in the Scopus database. Our search history in the Scopus database includes TITLE ("misconceptions") AND TITLE-ABS-KEY (biology)) AND PUBYEAR > 2013 AND PUBYEAR < 2025 AND (LIMIT-TO (SUBJAREA, "SOCI")) AND (LIMIT-TO (LANGUAGE, "English")) AND (LIMIT-TO (DOCTYPE, "ar")) AND (LIMIT-TO (PUBSTAGE, "final")) AND (LIMIT-TO (OA, "all")) AND (LIMIT-TO (SRCTYPE, "j")). With the search methods and strategies used, we managed to find 5823 articles with keyword misconceptions. We used the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) model to perform inclusion and exclusion. The model used as a reference in this study refers to Gallagher in their study using SLR.

The following important points are the basis for the inclusion criteria that we use in this SLR, namely: (1) the title of the article must contain the word "misconception"; (2) the title, abstract, or keywords must cover topics related to biology; (3) the article must be published after 2013 but before 2025; (4) the article must be classified under the field of Social Sciences (SOCI); (5) the article must be written in English; (6) the type of document must be an original article (ar); (7) the publication stage must be final; (8) the article must be available under Open Access (OA); and (9) the publication source must be a journal (j). The articles used are relevant to this study and related to biology in the context of social sciences, discussing several forms of misconception. This search was quite specific and interdisciplinary, focusing on how biology misconceptions intersect with the social sciences, which could include topics such as public understanding of biology, biology education, or the sociological implications of biology research. The order of inclusion and exclusion that we applied is shown in figure 1.

Based on figure 1, we found 5823 articles in the initial search. Next, we excluded 3859 articles that were not related to the field of social sciences. From the remaining articles, we obtained 1964 articles that were the focus of this study. After excluding 60 articles in languages other than English, 1904 articles remained in English. Articles that are not in English are often not included in the search data in this study for several reasons: language limitations of researchers, limited resources to translate articles, the dominance of English in international scientific literature, the efficiency of the review process and data analysis, and minimal impact on the overall conclusions of the systematic review or meta-analysis.[31]

Furthermore, 494 articles were excluded from conference papers, book chapters, reviews, notes, letters, and editorial books and retracted, resulting in 1410 original articles. The articles that are the focus of this study were published in the Scopus database between 2014 and 2024. Of the 717 articles that met the criteria, 693 articles were excluded. The 693 articles published before 2014 were excluded mainly to maintain the relevance and timeliness of the data used in this study. By limiting the focus to articles published between 2014 and 2024, this study can ensure that the data analyzed is the most up-to-date and relevant to the current state and context and takes into account the rapid development of technology and methodology in various disciplines.[32]

We also eliminated 396 paid articles, articles in the press, trade journals, and book series, resulting in 321 open-access articles, final articles, and retained journal articles. Open access to articles allows researchers to access research information without cost or accessibility restrictions, increases visibility, and enables the reuse of research results.[33] Using final articles in systematic literature reviews (SLRs) is essential to ensure that the information used is the final version, minimizing the risk of errors in interpretation or analysis.[28] Journal articles, which go through a peer-reviewed process, lend high credibility to the SLR analysis, ensuring that the research results in systematic literature reviews are valid and reliable.[34]

We eliminated 284 articles unrelated to biology and obtained 37 articles that met the criteria. The articles had the keyword "biology" listed in the article title, abstract, and keywords. Next, we excluded 7 articles based on their types: bibliometrics, physics materials, non-students, and review articles. Finally, we obtained 30 original articles that were relevant to this study, which we will examine and review further. In order to select articles with objectivity, we implemented several strategies, including translating articles into Indonesian, as our primary language, to facilitate understanding. The goal is to ensure the selected articles meet the inclusion and exclusion criteria.

RESULTS

Definition of Misconceptions According to Experts

There are 30 articles studied in this SLR from sources from the Scopus database. These articles present information on misconceptions that we have collected to deepen our understanding of the definition of misconceptions in biology learning, as seen in table 1 below.

The key terms in bold are used to define misconceptions in biology learning (figure 2). As a team, we highlighted some specific keywords related to misconceptions in biology learning, namely "understanding," the concept," "idea," and "interpretation." Highlighting these keywords can help me understand the definition of biology misconceptions and learn more deeply.

Table 1. Definition of misconceptions from the articles that were the focus of analysis in this study	
Information	**Reference**
The misconception is a correct understanding or accurate conception of a scientific concept or process students hold.	(2,7,8,23,26,35)
The misconception is an understanding that only conforms to correct scientific concepts.	(4,13,25,36)
Misconceptions are students' incorrect understandings of scientific concepts originating from everyday experiences, inappropriate teaching, or misunderstandings of the language in science.	(1,3,5,12,14,17,37,38)
Misconceptions are students' understandings that deviate from accepted scientific concepts, often from initial intuition or inaccurate information.	(39,40,41)
Misconceptions are students' ideas that do not correspond to scientific concepts because students create meaning based on incorrect personal experiences and knowledge.	(14,16,37)
Misconceptions are incorrect interpretations of students' biological concepts caused by students' hemispheric preferences.	(9,36,42)

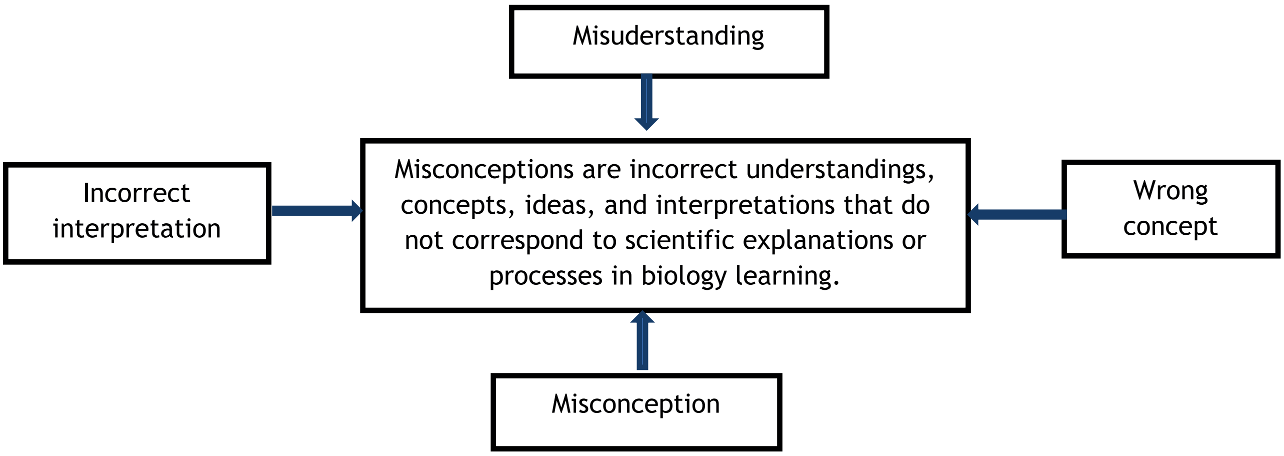

Figure 2. The process of defining misconceptions from various sources

Types of Misconceptions related to the topic of Biology in this study

This study also identified the types of misconceptions related to the topic. For example, many students assume that evolution occurs randomly or always leads to an increase in the complexity of organisms, which is contrary to the actual theory of evolution. There are also misconceptions about cell structure, where students often assume that all cells have the same shape and size. In addition, in genetics, misconceptions about the inheritance of traits. In ecology, students often misunderstand the energy flow in ecosystems as a linear process without complex cycles; more details can be seen in table 2.

Table 2. Types of misconceptions related to the topic of Biology in this study	
Information	**Reference**
Evolution	(1,14,17,22,36,37)
Genetics	(8,12,16,23,26,35)
Cell	(4,13,39,41,43)
Ecosystem	(44,45,46)
Basic concepts of biotechnology	(9,38)
Organ system	(5,6,40,42)
Nerves and Plant Taxonomy	(5,40)
Cell metabolism and health microbiology	(2,3)

Based on the data in table 2, the most common misconceptions in the first order are the topic of evolution. Next, in the second order, is the topic of genetics. The topic of cells is in the third order, while the topic of basic concepts of biotechnology and ecosystems is in the fourth order. Fifth, several topics include organ systems, nerves, plant taxonomy, cell metabolism, and health microbiology.

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The Impact of Misconceptions on Biology Learning

We conclude the impact of misconceptions in biology learning by reviewing various scientific articles. Misconceptions Impact students' conceptual understanding, affect scientific literacy and make it challenging to understand advanced concepts because learning is cumulative, where understanding new concepts depends on the correct understanding of previous concepts (table 3).

Table 3. The impact of misconceptions in biology learning in this study

Information	Reference
Impact on students' conceptual understanding	(1,2,6,7,8,9,39,42,44,47)
Influence on scientific literacy	(12,13,16,43)
Affects students' motivation to learn and decreases self-confidence	(3,14,17,23,37,40,45)
Difficulty in problem-solving	(17,26,41)
Resistance to new information	(4,26,41)
Negative attitudes toward science and difficulties in scientific communication	(22,38)

DISCUSSION

Definition of Misconceptions According to Experts

Definition of Misconception

A misconception is a wrong or inaccurate understanding that someone has about a concept.[18] It affects the learning process and reduces students' motivation toward science.[48] Inappropriate teaching and inaccurate information from teachers or other sources are often the causes of misconceptions that directly affect students' understanding of scientific concepts.[15,49] We updated the definition of misconception because the existing definition was inadequate, and we used previous research findings to build a more comprehensive definition. We obtained four keywords from a comprehensive literature review of the definition of misconception.

Misconception is a Wrong Understanding

Understanding is the foundation of all learning, including biology.[50] Understanding is the first key to overcoming misconceptions because correct understanding is the basis of effective learning.[15,16] Without correct understanding, concepts, ideas, interpretations, and scientific processes will be distorted, ultimately hindering the development of students' overall biological knowledge.[12] Misconceptions occur when students build their knowledge based on incorrect understanding.[11,15,51] Misconceptions are often difficult to change because students have integrated them into their cognition.[12,16] Educators can develop more effective strategies to identify and address these misconceptions.[15,16,18] That involves using diagnostic tests to detect misconceptions and evidence-based knowledge-construction learning methods.[14,18]

Misconception is a Wrong Concept

Misconceptions are beliefs inconsistent with scientific understanding or evidence and can significantly cause misconceptions.[12] Misconceptions can arise from various factors, including prior knowledge, cultural beliefs, and lack of exposure to scientific concepts.[52] Misconceptions can be particularly challenging to address in biology instruction, as they can be deeply ingrained and difficult to change.[52]

Misconceptions are often reinforced by personal experiences, anecdotal evidence, or cultural beliefs, making it difficult for students to accept accurate scientific information.[53,54] To address these challenges, it is essential to provide students with opportunities to engage in scientific inquiry.[52,55] In addition, providing accurate and reliable information and connecting scientific concepts to students' experiences and cultural backgrounds can help foster the development of accurate mental models.[19]

Misconception is a Wrong Idea

Misconceptions based on erroneous information can cause misconceptions in biology learning.[14,18] Misconceptions can arise from individual experiences and are often difficult to change because they reject new and accurate scientific information.[56] Misconceptions pose a significant challenge in biology learning, as they can be deeply ingrained and resistant to change.[5,40]

To address misconceptions, it is essential to provide students with opportunities to engage in scientific inquiry, with evidence-based reasoning and scientific methods to understand the natural world.[16,22] Through scientific inquiry, students challenge misconceptions, develop critical thinking skills, and contribute to advancing scientific knowledge.[52,57,58] Providing students with opportunities to engage in scientific inquiry helps challenge misconceptions and encourages the development of accurate mental models.[15,52] This helps students improve their understanding of biological concepts and scientific knowledge.[55,59,60]

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Misconception is an incorrect interpretation

Inappropriate interpretation is one of the leading causes of misconceptions.[15,61] Incomplete in formation, limited experience, and unreliable sources, such as hoaxes, can lead to misconceptions.[5] Misconceptions can also arise when someone tries to understand new information based on previous knowledge and experience.[62] Only complete or accurate knowledge can form misconceptions as new information is incorporated into existing mental frameworks.[15,63] Additionally, misconceptions can be reinforced if not challenged or corrected.[64] Educators must be aware of common misconceptions and design instruction that addresses and corrects them.[16]

Types of Misconceptions Related to Biology Topics

Students misconceptions regarding the topic of evolution

The topic of evolution challenges students because it is a complex process and involves concepts of genetics and natural selection.[14] Students experience misconceptions about evolution due to a lack of in-depth understanding of the theory's fundamental concepts.[37] Many students need more complete or accurate information on the topic from non-academic sources.[14] These misconceptions are often caused by ineffective teaching methods, where essential concepts are not explained in a way that is easy to understand.[18,22] For example, students need help understanding how natural selection works or how genetic mutations can cause changes in populations over time.[65] In addition, textbook errors or teaching materials can cause misconceptions.[17] Some books tend to present outdated or incomplete information about evolution.[14] That is exacerbated by the need for more need for adequate understanding from teachers who teach this topic. Teachers who feel uncomfortable or unsure about the material of evolution tend to avoid in-depth discussions, which ultimately reduces student understanding.[1] Misinterpreting evidence for evolution, such as fossils and genetic experiments, is also common.[14] Another factor is the influence of personal or cultural beliefs that often conflict with the concept of evolution.[22] Some students may come from backgrounds where evolution is controversial or inconsistent with their religious beliefs.[14] That can lead to resistance to accepting or studying the theory of evolution with an open mind.[17] In addition, discussions or debates in students' social environments can reinforce these misconceptions, making it even more difficult for students to accept the correct scientific explanation of evolution.[37]

Students misconceptions regarding the topic of genetics

Genetics is a complex topic that requires a strong understanding of basic concepts such as chromosomes, genes, and dominant/recessive traits.[8,23] Misconceptions often occur due to the complexity of these concepts, which require precise and structured explanations.[18] Lack of understanding of genetics material in students is often caused by ineffective teaching, lack of emphasis on basic concepts, or incomplete or outdated textbooks and teaching materials.[26]

In addition, low interest and motivation to learn also affect students' understanding of genetics.[47] Many students consider genetics difficult and tedious.[8] Teachers' inability to make this material interesting and relevant to students' daily lives often exacerbates this problem.[16] Teachers who are uncomfortable or less confident with genetics material tend to avoid in-depth discussions, which reduces students' understanding of essential concepts in genetics.[12]

Students misconceptions regarding the topic of cells

The topic of the cell is a complex biological entity with various internal structures such as mitochondria, ribosomes, and endoplasmic reticulum.[13] Students often need help understanding these structures and their roles in cell function due to their highly detailed and technical nature.[39] The topic of the cell involves integrating information about various organelles and biochemical processes that are difficult to understand if not appropriately explained.[41] In addition, the lack of emphasis on fundamental concepts in teaching can make it difficult for students to understand how these structures function together to support cell life.[13] Ineffective teaching methods also play a role in students' misconceptions about the topic of the cell.[22] A more interactive and problem-oriented approach may be more effective in helping students understand cell concepts and address misconceptions.[43] Using methods that engage students in an active learning process can improve students' understanding of this complex topic.[22]

Students misconceptions regarding the topic of basic biotechnology concepts

Due to the material's complexity, students need to be more accurate regarding basic biotechnology concept.[16] Biotechnology includes topics such as genetic engineering, tissue culture, and industrial applications of enzymes that require a deep understanding of DNA structure, replication processes, and gene expression.[38] With a strong biological foundation, students can understand and relate biotechnology concepts to their knowledge.[12,16]

In addition, ineffective teaching methods contribute to students' misconceptions.[18] One-way and less interactive teaching methods make students bored and not actively involved in learning.[66] The use of visual aids and relevant practicums can improve students' understanding, but without the right teaching approach, biotechnology concepts remain abstract.[9] Limited resources and learning materials also affect students' understanding.[22] They often do not have access to adequate laboratories or teaching aids to experience biotechnology processes directly, thus relying on theory without seeing its practical applications.[67]

Students misconceptions regarding the topic of ecosystems

Students' misconceptions about ecosystems occur due to the complexity of the concept,[17] ineffective teaching methods, and incorrect initial understanding.[22] Students often need help understanding the interactions of biotic and abiotic components because teaching is too theoretical and not contextual.[44] Non-interactive teaching approaches and minimal visual media or experiments worsen students' understanding of this topic.[68] Overcoming misconceptions requires a holistic and interactive teaching approach.[15] Teachers can use ecosystem simulations,[69] case studies, and field experiments to help students understand the complex interactions in ecosystems.[46] This approach allows students to see firsthand the interactions of ecosystem components and the impacts of change to build a more solid and comprehensive understanding.[45]

Misconceptions related to the topic of organ systems

Misconceptions about organ systems arise due to shallow understanding and simplification of information in primary education.[70] Many students think organs function independently without any connection to other organs, whereas organs work in a mutually supportive system to maintain optimal body function.[6]

In addition, misconceptions also arise from a need for an understanding of how disease affects organ systems.[18] Students think that disease only affects specific organs, whereas chronic diseases such as diabetes or hypertension can simultaneously affect multiple organ systems.[71] Awareness of the interconnections between organs and the impact of medical conditions on the entire body system is critical to understanding health and disease comprehensively.[42]

Students misconceptions regarding the topic of nerves

Misconceptions related to the nervous system arise due to the complexity of the material and the abstractness of concepts, such as the structure and function of neurons, nerve impulses, and the central and peripheral nervous systems.[40] This difficulty is exacerbated by the delivery of material that needs to be clarified in explaining these concepts.[72] Abstract materials such as the function of neurotransmitters and synapse mechanisms should be given adequate analogies or visualizations to facilitate student understanding.[73] Students' learning experiences and teaching methods play a significant role in the emergence of misconceptions.[17] Students tend to rely on previous learning experiences or information that is only partially correct.[22] Teaching less interactive methods that do not provide opportunities for discussion and clarification worsens this situation.[17]

Students misconceptions regarding the topic of plant taxonomy

Student misconceptions related to plant taxonomy occur because the complexity of taxonomic material involving the classification and characteristics of various types of plants is often difficult for students to understand.[5] These concepts require in-depth knowledge of plant morphology and physiology, which are often abstract and require good understanding.[74] Many students find this material too abstract and difficult to understand, mainly if it is not supported by interactive and exciting teaching methods.[75] Passive teaching methods and unclear textbooks contribute to misconceptions.[16]

Students' misconceptions regarding the topic of cell metabolism

Students' misconceptions related to cell metabolism occur due to the concepts' abstraction.[2] Cell metabolism involves complex biochemical processes such as the glycolysis pathway.[76] the Krebs cycle[2], and the electron transport chain.[77] These concepts require a deep understanding of chemical reactions and molecular interactions that students with a biology and chemistry background do not easily understand.[78] Students' inability to relate these concepts to real-world situations also exacerbates misconceptions.[14] Lack of practical experience and adequate visual illustrations are major contributing factors.[79]

Students misconceptions regarding the topic of health microbiology

Students' misconceptions about health microbiology occur due to the material's abstract nature, making it difficult for students to understand essential concepts.[3] Lack of visualization and practical experience also worsens their understanding.[80] In addition, intrinsic factors such as how students process the information they have received also contribute to misconceptions.[22] Students also have difficulty linking microbiology concepts to real-world applications in human health.[81] The delivery of material that is too theoretical without the context of application in everyday life further complicates students' understanding.[68]

The Impact of Misconceptions on the Student Learning Process

Impact on Students' Conceptual Understanding

Misconceptions significantly impact students' conceptual understanding, especially in advanced concept learning.[9,39] These misconceptions can lead to academic assessment and decision-making difficulties and hinder effective learning processes.[6,47] Students need help refining their understanding and comprehending related topics and applying knowledge in real-world situations or different contexts.[7] These misconceptions also hinder effective instruction, making it easier for students to grasp complex ideas critical to scientific literacy.[8]

Misconceptions hinder the understanding of the principles of a particular topic and interfere with students' overall understanding.[2,44] These misunderstandings lead to a more substantial knowledge base, impacting their ability to integrate new information properly and reducing self-confidence and motivation.[1] As a result, the teaching and learning process becomes less effective, and students need help achieving higher educational goals.[42]

Influence on Scientific Literacy

Misconceptions directly affect scientific literacy.[16] Scientific literacy includes understanding basic concepts, thinking critically, and applying scientific knowledge in everyday life.[12] When students have a misconception about scientific principles, their ability to think critically and solve problems is limited.[43] These misconceptions can lead to misinterpretation of scientific data, inability to connect different concepts, and failure to follow the scientific process correctly.[15,17]

Scientific misconceptions hinder scientific literacy, affecting participation in scientific discussions and knowledge-based decision-making.[13] Students also need help understanding modern technology and science developments, making them less prepared to face future challenges.[12] Therefore, educators need to identify and correct misconceptions early on so that students' scientific literacy is robust and holistic.[16,82]

Influence on Student Learning Motivation

Misconceptions affect students' learning motivation.[16,17,22] Students who experience repeated difficulties in understanding the material due to incorrect initial concepts tend to feel frustrated and lose interest in learning.[14] The inability to overcome these difficulties can cause students to feel that their efforts must be paying off.[37] Ultimately, this feeling reduces motivation to learn further.[40] In addition, repeated errors due to misconceptions can make students feel incapable, which worsens learning motivation.[45]

Educators must identify and correct misconceptions early on to maintain learning motivation.[22] They must also provide the necessary support and appreciate students' efforts in understanding the material.[16] In this way, students' learning motivation can be maintained and continue to develop in the learning process.[17]

Resulting in a Decreased Self-Confidence

Misconceptions can significantly reduce students' self-confidence.[40] When students repeatedly find their understanding wrong, they need help to answer questions or solve problems correctly.[15,22] As a result, their self-confidence decreases. Low self-confidence can cause students to be reluctant to participate in class, avoid academic challenges, and feel anxious about assessments.[14] Low self-confidence creates a negative habit that prevents students from learning more effectively.[37] That exacerbates students' misconceptions.[45]

Therefore, educators must build a supportive learning environment.[17] Educators should provide constructive feedback and help students develop self-confidence through successful learning and positive experiences in understanding scientific concepts.[16] By doing this, educators can help students overcome misconceptions and increase motivation and effectiveness.[17,22]

Difficulty in Problem-Solving

Difficulty in problem-solving refers to the challenges students face when finding solutions to scientific problems or questions.[23] These challenges come in forms ranging from difficulty understanding basic concepts to difficulty applying existing knowledge to solve more complex scientific problems.[3] Solving scientific problems requires critical thinking skills, essential conceptual solutions, and applying knowledge in new situations.[17] When one or more of these elements are unmet, students have difficulty finding practical solutions to scientific problems.[15,56]

In addition to misconceptions, a lack of conceptual understanding and critical thinking skills hinder scientific problem-solving.[17] Without critical thinking skills, students struggle to analyze information, ask relevant questions, and make evidence-based decisions.[23] These skills can be developed through structured practice and learning, but without a specific approach, students will not develop these abilities effectively.[3]

Resistance to New Information

Resistance to new information is the tendency of students to reject or have difficulty accepting scientific information that conflicts with their beliefs.[4] This attitude often arises when students are confronted with concepts that differ from their old understandings.[15,41] That can be caused by various factors, including discomfort with change or difficulty realizing their beliefs are wrong.[26] Students tend to feel threatened by information inconsistent with their existing views.[83] Students with old beliefs or misconceptions about scientific concepts often feel threatened by new information.[15,52]

Resistance in students often manifests as rejecting new ideas that conflict with their beliefs.[4] Students tend to ignore or downplay scientific information that does not align with their views.[84] They also need help connecting new information to existing knowledge, which can hinder the development of scientific understanding.[26]

Negative attitudes towards science

Negative attitudes toward science refer to views or dislike toward science lessons.[38,85] This attitude can hinder students' engagement and motivation in science lessons.[52] This attitude appears to be disinterested, boredom, or even rejection of the material taught in science lessons.[86] Students with negative attitudes toward science feel that science is a tedious, complex, or irrelevant subject to their daily lives.[86]

Unpleasant learning experiences in the past can lead to negative attitudes towards science.[17,22] Failure to understand the material or see the relevance of science in everyday life makes students feel that science is unimportant or uninteresting.[87] External factors such as family or media influences can also contribute.[88] If students grow up in an environment that views science as unimportant, they are likelier to adopt that view.[55] These negative attitudes hinder students' engagement and motivation, reinforce misconceptions and cause them to avoid science assignments, discussions and experiments.[38]

Difficulties in Scientific Communication

Difficulties in scientific communication are a significant challenge for students, especially in conveying and understanding scientific information effectively, both orally and in writing.[22] Scientific communication involves explaining concepts, presenting data, and debating with an audience.[89] Students often need help to convey scientific material clearly.[90] One of the main difficulties is conveying scientific information, especially orally.[38] When speaking in front of a class or group presentation, students must construct coherent arguments,[90] explain concepts in easy-to-understand language, and answer audience questions.[91] Lack of speaking practice and inability to simplify technical information often cause these difficulties.[15]

In addition to oral communication challenges, students need help with written scientific communication.[56,92] Writing scientific reports, essays, or articles requires organizing information systematically and clearly.[93] These difficulties arise from a lack of understanding of the scientific format, formal language, and illogical data presentation.[94] To overcome scientific communication misconceptions, practice regularly.[16] This scientific communication needs to be developed through practice and constructive feedback.[95] Students cannot develop practical scientific communication skills.[38]

Strategies to Address Misconceptions for Educators

We recognize the importance of clear and practical strategies to assist educators in overcoming misconceptions in biology education. Therefore, we propose several actionable steps, including: first, employing the conceptual change model that actively engages students in identifying and reflecting on their misunderstandings. Second, integrating the use of visual media and interactive simulations to facilitate the comprehension of abstract concepts. Third, conducting diagnostic assessments at the beginning of instruction to identify the most prevalent misconceptions, enabling targeted and effective interventions. Lastly, encouraging group discussions and peer teaching methods to allow students to collaboratively correct and improve their understanding.

The Influence of Community Beliefs or Culture on Misconceptions

In our discussion, we highlight how certain local beliefs and cultural factors reinforce misconceptions, especially in the context of biology education in rural areas. For example, myths about the origins of plants or animals that contradict scientific facts still significantly affect students' understanding. This indicates that cultural aspects cannot be ignored and must be integrated into culturally sensitive teaching approaches to effectively reduce misconceptions.

Dependence on Scopus and Its Impact on Review Completeness

We acknowledge that relying solely on articles indexed in Scopus may limit the comprehensiveness of the literature review. To anticipate this limitation, we conducted cross-checks with other sources, including reputable national journals and relevant textbooks. However, focusing on Scopus provides a high standard of quality and allows for the analysis of global research trends. We will emphasize this limitation in the discussion section and recommend further studies that include a broader range of sources.

CONCLUSIONS

This study reveals that misconceptions in biology education are a common phenomenon that significantly affects students' teaching and learning processes. However, the literature review shows a considerable reliance on Scopus-indexed articles, which may limit the comprehensiveness and diversity of the review. Therefore, further research with a more inclusive approach to other sources, including reputable national journals and non-traditional educational settings, is highly recommended to enrich the understanding of misconceptions across various educational contexts.

The main types of misconceptions identified in this study include evolution, genetics, and cell biology as the topics with the highest prevalence of misconceptions. Basic biotechnology and ecosystems also exhibit significant misconceptions, while topics such as organ systems, nervous systems, plant taxonomy, cellular metabolism, and health microbiology have lower but still notable misconceptions requiring attention. The impacts of these misconceptions are wide-ranging, from diminished conceptual understanding and scientific literacy to decreased motivation and self-confidence among students. Misconceptions also cause difficulties in problem-solving, rejection of new information, negative attitudes toward science, and barriers to scientific communication.

Based on these findings, we propose the need for further studies focusing on correcting misconceptions, especially in underrepresented regions and non-traditional educational environments. Learning approaches that are sensitive to cultural and local contexts are expected to help reduce misconceptions and improve the overall quality of biology education.

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AUTHORSHIP CONTRIBUTION
Conceptualization: Rikardus Herak, Susriyati Mahanal, Siti Zubaidah, Vivi Novianti.
Data curation: Rikardus Herak, Susriyati Mahanal, Siti Zubaidah, Vivi Novianti.
Research: Rikardus Herak, Susriyati Mahanal, Siti Zubaidah, Vivi Novianti.
Methodology: Rikardus Herak, Susriyati Mahanal, Siti Zubaidah, Vivi Novianti.
Project management: Rikardus Herak, Susriyati Mahanal, Siti Zubaidah, Vivi Novianti.
Resources: Rikardus Herak, Susriyati Mahanal, Siti Zubaidah, Vivi Novianti.
Software: Rikardus Herak, Susriyati Mahanal, Siti Zubaidah, Vivi Novianti.
Supervision: Rikardus Herak, Susriyati Mahanal, Siti Zubaidah, Vivi Novianti.
Validation: Rikardus Herak, Susriyati Mahanal, Siti Zubaidah, Vivi Novianti.
Display: Rikardus Herak, Susriyati Mahanal, Siti Zubaidah, Vivi Novianti.
Drafting original draft: Rikardus Herak, Susriyati Mahanal, Siti Zubaidah, Vivi Novianti.
Writing-proofreading and editing: Rikardus Herak, Susriyati Mahanal, Siti Zubaidah, Vivi Novianti.