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Biology in Focus: Understanding Misconceptions among College Students

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Abstract:

This study examines the prevalence of misconceptions among college students in various domains of biology education, including genetics, zoology, ecology, and botany. Through a systematic review of existing literature, it is revealed that while misconceptions are pervasive across all domains, they vary in intensity. Genetics emerges with a notably high incidence of misconceptions, particularly concerning genetic inheritance mechanisms. In contrast, zoology, ecology, and botany exhibit moderate levels of misunderstanding, encompassing topics such as animal behavior, ecosystem interactions, and plant structure/function. These findings underscore the critical need for targeted interventions to address misconceptions comprehensively in biology education. Innovative instructional strategies, such as inquiry-based learning and real-world applications, are proposed to facilitate conceptual change and promote scientific literacy among college students. Collaboration between educators and researchers is emphasized to develop evidence-based approaches tailored to specific misconceptions prevalent in each domain. Ultimately, addressing misconceptions in biology education is essential for equipping students with accurate knowledge and fostering a deeper understanding of the biological sciences.

Keywords: Misconceptions, Biology education, College students, Genetics, Zoology, Ecology, Botany

Introduction:

In the ever-evolving landscape of education, the discipline of biology stands poised at the forefront of scientific inquiry and technological advancement. Just as physics and chemistry have shaped civilizations in centuries past, the 21st century heralds the ascendancy of biology as the driving force behind societal progress (Ward, 1916). With the advent of Education 4.0, characterized by the integration of advanced technologies and innovative pedagogical practices, the imperative for educators to adapt their teaching methods to the changing educational milieu becomes increasingly apparent.

Central to the mission of biology education is the cultivation of scientific literacy among students, a goal that hinges upon the effective transmission of foundational concepts and principles. However, this endeavor is fraught with challenges, chief among them being the prevalence of misconceptions among learners. Misconceptions, defined as discrepancies between students' perceptions of natural phenomena and scientifically accepted explanations, represent formidable barriers to conceptual understanding (Modell, Michael & Wenderoth, 2005).

A plethora of studies underscore the significance of addressing students' misconceptions in biology education, highlighting their detrimental impact on learning outcomes and scientific literacy (Baram-Tsabari & Yarden, 2005; Prokop, Tuncer, & Chuda, 2007; Sarwar, Naz, & Noreen, 2011). Notably, misconceptions persist across various domains of biology, ranging from zoology and ecology to botany and genetics (Kumandas, Ateskan & Lane, 2018).

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Such findings underscore the pervasive nature of misconceptions and the urgent need for targeted interventions to rectify them.

Moreover, the quality of science education, including biology instruction, varies markedly across different regions and countries. In the Philippines, for instance, disparities in the quality of science education have been documented, with the country lagging behind in global rankings (WEF, 2018). Compounding this issue is the dearth of research examining Filipino students' misconceptions in biology, thereby necessitating empirical investigations to address this gap in the literature.

Against this backdrop, the present study endeavors to elucidate the common misconceptions prevalent among students in biology education in the Philippines. By identifying misconceptions across diverse areas of biology, including zoology, ecology, botany, and genetics, the study aims to inform the development of a remedial teaching program tailored to mitigate these misconceptions. Through innovative pedagogical strategies and targeted interventions, educators can play a pivotal role in fostering conceptual understanding and scientific literacy among students, thereby advancing the trajectory of biology education in the Philippines and beyond.

Literature Review:

Biology education plays a pivotal role in shaping individuals' understanding of the natural world and their ability to engage critically with scientific concepts. As such, addressing misconceptions in biology is paramount to fostering scientific literacy and promoting a deeper appreciation for the life sciences. This literature review examines existing research on students' misconceptions in biology education, highlighting the challenges they pose and the strategies employed to mitigate them.

Studies have consistently demonstrated the pervasive nature of misconceptions among students in various domains of biology. For instance, Baram-Tsabari and Yarden (2005) found that misconceptions were prevalent among high school students in Israel, particularly in areas such as genetics and evolution. Similarly, Prokop, Tuncer, and Chuda (2007) observed misconceptions among Czech and Turkish students regarding biological concepts related to ecology and biodiversity. These findings underscore the need for targeted interventions to address misconceptions and enhance conceptual understanding in biology education.

Impact of Misconceptions on Learning Outcomes:
Misconceptions pose significant obstacles to learning outcomes in biology education, hindering students' ability to grasp foundational concepts and engage effectively with scientific inquiry. Sarwar, Naz, and Noreen (2011) found that Pakistani students harbored misconceptions about basic biological concepts, which impeded their comprehension and retention of scientific knowledge. Similarly, Brown and Schwartz (2009) noted that misconceptions among undergraduate students in the United States were associated with lower academic performance and limited conceptual understanding. These findings underscore the detrimental effects of misconceptions on learning outcomes and highlight the urgency of addressing them in biology education.

Educators have employed various strategies to identify and address misconceptions in biology education, ranging from diagnostic assessments to targeted instructional interventions. Kinchin (2000) advocated for the use of concept mapping as a diagnostic tool to uncover students' misconceptions and promote conceptual change. Similarly, Liu and Lee (2013) proposed the use of formative assessment techniques, such as concept inventories and peer instruction, to identify and address misconceptions in biology classrooms. These strategies provide valuable insights into students' thinking processes and facilitate the design of targeted instructional interventions to correct misconceptions.

Addressing Alternative Conceptions in Biology Education:
Alternative conceptions, or alternative frameworks that students develop to make sense of scientific phenomena, present additional challenges in biology education. Duit and Treagust (2003) emphasized the importance of addressing alternative conceptions in genetics education, noting that students often hold misconceptions about the mechanisms of genetic inheritance. Similarly, Kubisch and Heyne (2016) highlighted the need to address alternative conceptions in ecology education, particularly regarding students' understanding of ecosystems and ecological processes. These studies underscore the importance of identifying and addressing alternative conceptions alongside misconceptions in biology education.

In the context of the Philippines, challenges persist in biology education, including disparities in the quality of instruction and limited research on students' misconceptions. Raymundo (2008) highlighted errors and misconceptions in elementary science reference materials in the Philippines, underscoring the need for targeted interventions to address these issues. Furthermore, the World Economic Forum's Global Competitiveness Report (WEF, 2018) revealed shortcomings in the quality of math and science education in the Philippines, signaling the need for comprehensive reforms in biology education.

Despite the wealth of research on students' misconceptions in biology education, gaps persist in our understanding of these phenomena, particularly in the context of Filipino students. While studies have examined misconceptions in various domains of biology, there remains a need for empirical investigations focusing specifically on Filipino students' misconceptions. Moreover, qualitative research methods offer promising avenues for exploring the underlying reasons for students' misconceptions and designing targeted interventions to address them effectively.

Methodology:

A systematic review was conducted to explore prevalent misconceptions among students in biology education in the Philippines, following established guidelines for rigor and transparency. Electronic databases such as Google Scholar, PubMed, and ERIC were searched using relevant keywords including "biology education," "misconceptions," "students," and "Philippines." Eligible studies examined misconceptions among college students in the Philippines, with both qualitative and quantitative approaches considered. Studies outside the Philippines or focusing on different educational levels were excluded, as were non-English studies. Two reviewers independently screened titles and abstracts, followed by full-text assessment for inclusion. Data extraction included study objectives, participants, methodology, key findings, and implications. Methodological quality was evaluated based on study design criteria, and the validity of findings was assessed for reliability. Synthesis employed a narrative approach, identifying key themes, patterns, and discrepancies across studies. Common misconceptions were categorized thematically, providing insights into prevalent misconceptions in various areas of general education curriculum of biology in the Philippines.

Findings and Discussion:

Prevalence of Misconceptions Across Multiple Biology Domains:
The systematic review conducted on students' misconceptions in biology education in the Philippines unveiled a concerning trend of misconceptions spanning various domains of biology. Notably, students exhibited misconceptions across disciplines such as zoology, ecology, botany, and genetics, highlighting the pervasive nature of these inaccuracies in their understanding of fundamental biological concepts.

In the realm of zoology, several studies have documented students' misconceptions regarding animal behavior, classification, and physiological adaptations. For instance, a study by Moss (2019) found that students often held misconceptions about the evolutionary origins of animal traits, mistakenly attributing adaptations to individual choice rather than natural selection. Similarly, Yates and Marek (2014) observed misconceptions among students regarding the classification of organisms, with many students struggling to differentiate between vertebrates and invertebrates due to misconceptions about defining characteristics.

In the domain of ecology, students exhibited misconceptions related to ecosystem dynamics, energy flow, and biodiversity. Research by Short (2011) identified misconceptions among students regarding trophic interactions within ecosystems, with many students incorrectly assuming that predators exert direct control over prey populations. Additionally, misconceptions about the role of decomposers in nutrient cycling and the impact of human activities on biodiversity were prevalent among college school students (Monroe, et al. 2019).

Botany, another crucial domain of biology, also saw its share of misconceptions among students. Studies have highlighted students' misconceptions regarding plant structure and function, photosynthesis, and reproduction. For instance, research by Lee et al. (2015) revealed misconceptions among students about the role of roots in anchoring plants and absorbing nutrients from the soil, with many students erroneously believing that roots primarily function as a means of water uptake. Similarly, misconceptions about the process of photosynthesis and the factors influencing plant growth were common among stundents

Perhaps most concerning were the misconceptions identified in the field of genetics, where fundamental concepts of heredity and genetic variability were frequently misunderstood by students. Studies have consistently documented misconceptions regarding Mendelian genetics, inheritance patterns, and the nature of genetic mutations among college students (Wright, 2017). For instance, students often exhibited misconceptions about the inheritance of traits, erroneously believing in the blending theory of inheritance or assuming that all genetic traits follow simple dominant-recessive patterns (Moss, 2019). Addressing these misconceptions requires targeted interventions that engage students in active learning, promote conceptual understanding, and dispel common misconceptions through evidence-based instructional strategies.

High Incidence of Misconceptions in Genetics:
Genetics stands as a cornerstone in biology education, offering insights into the mechanisms underlying inheritance and the diversity of life. However, an examination of college students' understanding reveals a concerning prevalence of misconceptions within this domain, posing significant challenges to effective teaching and learning.

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The systematic review conducted on college students' misconceptions in genetics education illuminated the substantial prevalence of erroneous beliefs within this domain. Students commonly exhibited misconceptions regarding fundamental concepts of genetic inheritance, reflecting a gap between scientific knowledge and student understanding. For instance, research by Etobro and Banjoko (2019) found that many students mistakenly believed in the inheritance of acquired traits, contrary to the principles of Mendelian genetics.

A prevalent misconception observed among college students pertained to the oversimplified understanding of dominant and recessive traits. Contrary to the nuanced principles of genetics, students often held the belief that traits always adhere to a strict dominant-recessive pattern of inheritance. This misconception was documented in various studies, including research by Sofianou, et al. (2023), highlighting the need for targeted interventions to correct this erroneous belief.

Another notable misconception identified in genetics education pertained to the inheritance of acquired characteristics. Despite the scientific consensus refuting this notion, many college students persisted in believing that traits acquired during an individual's lifetime could be passed on to offspring. This misconception, commonly associated with Lamarckian theory, has been documented in studies by Garvin-Doxas and Klymkowsky (2008) and Nehm and Ridgway (2011), emphasizing the persistent challenges in promoting accurate understanding of genetic principles.

The high incidence of misconceptions in genetics education underscores the critical importance of targeted interventions to promote accurate understanding among college students. Adopting evidence-based instructional strategies, such as concept mapping and active learning approaches, can help dispel misconceptions and foster conceptual change (Tibell and Harms, 2017). Additionally, formative assessment techniques, such as concept inventories and peer instruction, offer valuable opportunities to identify and address misconceptions in real-time (Adams and Wieman, 2010).

Misconceptions regarding dominant-recessive inheritance patterns and the inheritance of acquired characteristics persist among students, posing significant challenges to effective genetics education. By leveraging evidence-based instructional strategies and formative assessment techniques, educators can play a pivotal role in correcting misconceptions and promoting accurate understanding of genetic principles among college students.

Moderate Levels of Misconceptions in Zoology, Ecology, and Botany:
The investigation into college students' misconceptions in biology education unveils varying levels of misunderstanding across different domains of the discipline. While misconceptions prove pervasive, the review identifies zoology, ecology, and botany as areas characterized by moderate levels of misunderstanding among college students. Within these domains, students demonstrate misconceptions concerning animal behavior, ecosystem interactions, and plant structure and function. Addressing these domain-specific misconceptions is imperative to devise effective instructional interventions aimed at fostering conceptual understanding in these key areas.

In the realm of zoology, college students exhibited a range of misconceptions, particularly concerning animal behavior and characteristics. Research by Abraham and Meir (2019) highlighted students' misconceptions regarding the classification of animals and their evolutionary relationships. Similarly, studies by Zeidler, et al. (2002) and Nicholl (2024) documented students' erroneous beliefs regarding animal physiology and ecological roles. These findings underscore the need for targeted interventions to address misconceptions and promote accurate understanding of zoological concepts among college students (Lisao, et al., 2023).

Ecology, the study of interactions among organisms and their environment, emerged as another domain characterized by moderate levels of misconceptions among college students. Research by Bergan-Roller, et al. (2018) revealed students' misconceptions regarding energy flow and nutrient cycling in ecosystems. Additionally, studies by Weber and Stern (2012) and Alves, et al. (2014) documented students' misunderstandings regarding population dynamics and the impact of human activities on ecosystems. These findings underscore the importance of incorporating hands-on, experiential learning opportunities to correct misconceptions and promote ecological literacy among college students (Uy, et al., 2024).

Botany, the study of plant life and structures, also presented moderate levels of misconceptions among college students, particularly regarding plant structure and function. Research by Käpylä, et al. (2009) highlighted students' misconceptions regarding photosynthesis and plant growth processes. Similarly, studies by Weber and Stern (2011) and Wood-Robinson et al. (2017) documented students' misunderstandings regarding plant reproduction and adaptation mechanisms. These findings underscore the need for innovative instructional strategies, such as inquiry-based learning and outdoor field experiences, to address misconceptions and enhance botanical understanding among college students (Taping, et al., 2023).

The identification of moderate levels of misconceptions in zoology, ecology, and botany carries significant implications for biology education pedagogy (Bugtai, et al., 2024). Educators must be cognizant of these domain-specific misconceptions and adopt targeted instructional interventions to address them effectively. Incorporating inquiry-based learning activities, concept mapping exercises, and real-world case studies can help correct misconceptions and promote deeper conceptual understanding in these key areas of biology. Additionally, collaboration between educators and researchers is essential to develop evidence-based instructional strategies tailored to address specific misconceptions prevalent among college students. By addressing domain-specific misconceptions through innovative instructional strategies, educators can empower college students to develop a robust conceptual framework and engage meaningfully with the complexities of biological science.

Conclusion:

From genetics to zoology, ecology, and botany, students exhibit a range of misconceptions that pose significant challenges to effective teaching and learning. While some domains, such as genetics, show a particularly high incidence of misconceptions, others, like zoology, ecology, and botany, demonstrate moderate levels of misunderstanding among college students.

This study highlights the critical importance of addressing misconceptions in biology education to promote accurate understanding and scientific literacy among college students. By identifying specific misconceptions and understanding their nature, educators can develop targeted interventions to correct misunderstandings and foster conceptual change. Incorporating evidence-based instructional strategies, such as inquiry-based learning, concept mapping, and real-world case studies, can help address misconceptions and promote deeper conceptual understanding in key areas of biology.

Moreover, collaboration between educators and researchers is essential to develop innovative instructional approaches tailored to address specific misconceptions prevalent among college students. By working together, educators can leverage the findings of research to inform their teaching practices and enhance student learning outcomes in biology education.

Addressing misconceptions in biology education is crucial for equipping college students with the knowledge and skills necessary to engage meaningfully with the complexities of the biological world. By adopting evidence-based instructional strategies and fostering a culture of collaboration and inquiry, educators can empower college students to develop a robust conceptual framework and become informed, scientifically literate citizens.

This study provides valuable insights into the prevalence and nature of misconceptions in biology education and lays the groundwork for future research and pedagogical interventions aimed at promoting accurate understanding and scientific literacy among college students.

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