Diagnostic Analysis of Preservice Elementary Teachers' Misconceptions on Biomes and Ecosystem Diversity Using Certainty of Response Index

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Abstract: Misconceptions are understandings that do not align with scientific concepts and can hinder the learning process, particularly among prospective elementary school teachers who will be teaching science concepts to students. This study aims to identify and analyze misconceptions among PGSD students regarding the diversity of biomes and ecosystems. The study employed a quantitative descriptive method using a survey technique involving the distribution of a questionnaire assisted by the Certainty of Response Index (CRI) to 38 second-semester PGSD students at the University of Nias. Data were analyzed descriptively based on the percentage of student responses to each statement. The results indicate that significant misconceptions persist regarding several concepts, including the relationship between ecosystem diversity and genetic and species diversity (84.2%), the concept of biomes and their components (78.9%), the impact of deforestation on ecosystems (73.7%), the characteristics of the tundra biome (55.3%), and the effects of poaching and water pollution on ecosystem balance (52.6%). Further analysis indicates that the misconceptions identified can be categorized into substitution misconceptions, failure to transfer knowledge across concepts, and erroneous ecological beliefs based on everyday experience. These findings suggest that PGSD students still face difficulties in understanding and connecting ecological concepts.

Keywords: misconceptions, elementary education students, biome diversity, ecosystem.

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Introduction

One of the topics in natural science education is the diversity of biomes and ecosystems, as it explores the relationship between living organisms and their environment. The diversity of a community consisting of animals, plants, and microorganisms within a specific habitat is referred to as ecosystem diversity. On the other hand, ecosystem diversity can be defined as the relationships or interactions between living organisms with one another and with their environment (Artanti, 2020). This material helps students understand various types of ecosystems and biomes, the factors that shape biomes, and the biotic and abiotic interactions that occur in nature. Therefore, this material serves as an important foundation for studying various environmental phenomena.

An ecosystem is a system formed by the reciprocal relationships between living organisms-known as biotic components and their physical environment, or abiotic components (Rahayu C. et al., 2025), whereas a biome is a group of ecosystems that share similar characteristics in terms of climate, vegetation, and organisms. These two concepts are interrelated but have different focuses of discussion. In practical learning, students often have difficulty distinguishing between ecosystems and biomes because. both deal with living environments.

A misconception is defined as a student's understanding that does not align with the correct understanding; it is only found in specific situations and does not apply to others, nor can it be generalized (Rahayu, 2018). Misconceptions or misunderstandings can arise from daily experiences, inappropriate learning materials, improper teaching methods, or personal interpretations of concepts. In science education, misconceptions are a problem that requires attention because they can hinder the process of developing new knowledge. If not identified early on, misconceptions will persist into higher education.

Elementary School Teacher Education (PGSD) students play a crucial role as future educators who will teach science concepts to elementary school students. Therefore, a deep understanding of these concepts is essential to prevent the spread of misconceptions to students in the future. Indeed, elementary teacher education students should possess a strong understanding of the concepts of biomes and ecosystem diversity. However, findings indicate that students still exhibit conceptual errors regarding the material.

Furthermore, previous studies have not examined which conceptual indicators are most prone to misconceptions. Furthermore, differences in the objectives and methods used highlight the limitations of previous research. Most studies only examine the extent to which concepts are well understood, without identifying the types of misconceptions that arise. Other studies cannot provide a comprehensive picture of students' conceptual understanding

because they measure only learning outcomes. Consequently, information regarding the characteristics of PGSD students' misconceptions related to biomes and ecosystems remains incomplete and requires further research.

Based on the above discussion, there is a need for researchers capable of identifying and analyzing PGSD students' misconceptions regarding biomes and ecosystems in greater depth. A key question that needs to be answered is the extent of PGSD students' misconceptions regarding biome and ecosystem material, as well as which concepts are most frequently affected by these misconceptions. This study is expected to provide accurate information regarding the students' level of understanding. Furthermore, the results of this study are expected to serve as a foundation for developing more effective learning strategies to prevent the occurrence of misconceptions.

Methods

This study employed a quantitative descriptive method. Data collection was conducted through a survey and the distribution of an online questionnaire via Google Forms to PGSD students on a voluntary basis. The instrument used was a questionnaire designed to identify misconceptions regarding the diversity of biomes and ecosystems, supplemented by the Certainty of Response Index (CRI). The CRI is a measurement method used to detect the level of confidence or certainty respondents have in the answers they provide. The population consisted of 38 PGSD students in Class C, Semester 2, at the University of Nias.

Data analysis in this study employed a descriptive quantitative approach to understand the level of students' misconceptions regarding the material on the diversity of biomes and ecosystems. Information was derived from the students' test responses, which were then directly analyzed based on the answer choices selected by the students. Each student's response was categorized into agreement groups, including strongly agree, agree, undecided, somewhat agree, and disagree. These categories were determined by considering the accuracy of the answers and the students' level of confidence in their choices. Additionally, each question was analyzed to identify the components of the material most frequently subject to misconceptions. The results of this process are presented in the form of tables, graphs, and narrative explanations to illustrate the overall patterns of student understanding.

Results

This study reveals a key scientific finding: the presence of systematic, cross-conceptual misconceptions among 38 elementary education students regarding their understanding of the diversity of biomes and ecosystems. The misconceptions found are not merely factual ignorance, but rather erroneous beliefs held as true (Suparno, 2013), and manifest in three main patterns to be discussed below: (1) concept substitution, (2) failure to transfer knowledge across concepts, and (3) erroneous ecological beliefs based on everyday experience. These findings are scientifically significant because the research subjects are prospective teachers, so the implications are multiplicative unaddressed misconceptions have the potential to be propagated to the generations of students they will teach (Loughran et al., 2006).

Overall, the distribution of students' responses to the 20 statements is presented in Table 1. It should be noted that the asterisk (*) next to a statement identifies an item that is scientifically incorrect; thus, "Agree" and "Strongly Agree" responses to that item reflect misconceptions, not correct understanding.

Table 1. Percentage Distribution of PGSD Student Responses

No.	Statement	SS (%)	S (%)	CS (%)	RR (%)	TS (%)
1	Ecosystem diversity results from genetic and species diversity	28,9	55,3	7,9	5,3	2,6
2	An ecosystem is the reciprocal relationship between living organisms and their environment	31,6	57,9	5,3	5,3	0,0
3	Biomes are formed due to geographical/astronomical factors; they consist of producers, consumers, and decomposers*	26,3	52,6	7,9	7,9	5,3
4	Humans play a significant role in the distribution of flora and fauna	39,5	39,5	10,5	7,9	2,6
5	Rainfall and wind affect plant distribution	36,8	42,1	10,5	10,5	0,0
6	Altitude affects the types of flora and fauna	26,3	52,6	10,5	10,5	0,0
7	The tundra biome has very high biodiversity due to abundant rainfall*	21,1	34,2	10,5	13,2	21,1
8	Tropical rainforests are rich in species due to stable temperatures and rainfall	26,3	50,0	10,5	10,5	2,6
9	Savannas are characterized by the dominance of grasses and the alternation of wet and dry seasons	34,2	42,1	10,5	13,2	0,0
10	Biotic and abiotic components interact to maintain ecosystem balance	39,5	42,1	13,2	5,3	0,0
11	Biotic: living organism; abiotik: water, soil, light, temperatures	36,8	50,0	5,3	7,9	0,0
12	A disturbance in one component affects the balance of the entire ecosystem	36,8	39,5	7,9	13,2	2,6
13	Ecosystem diversity is formed due to differences in environmental factors	34,2	39,5	7,9	15,8	2,6

14	A biome is a group of ecosystem with similar climate, soil, and vegetation characteristics	31,6	42,1	13,2	13,2	0,0
15	A biome is a grouping of ecosystems based on similar environmental conditions	39,5	39,5	13,2	7,9	0,0
16	Ecosystem function to maintain balance through nutrient cycles and carbon storage	28,9	44,7	7,9	15,8	2,6
17	Healthy biomes support the sustainability of large-scale ecosystem functions	36,8	42,1	7,9	10,5	2,6
18	Deforestation affects the ecosystem as long as there are remaining plants*	23,7	50,0	10,5	7,9	7,9
19	Poaching does not disrupt the ecosystem because the population recovers in its own*	21,1	31,6	10,5	10,5	26,3
20	Discharge of waste into water bodies has no effect on aquatic habitats*	18,4	34,2	13,2	2,6	31,6

Notes: SS = Strongly Agree, S = Agree, CS = Somewhat Agree, RR = Undecided, TS = Disagree. (*) = scientifically incorrect statement; responses of SS and S to this item indicate a misconception.

The first and most prominent finding was a substitutional misconception, which is a condition in which a correct scientific concept is completely replaced by an incorrect one within students' cognitive structures (Mintzes et al., 2001). This is evident in Statement 1, where 84.2% of students believe that ecosystem diversity is a derivative of genetic and species diversity a hierarchical association with reversed causality. Scientific evidence indicates that ecosystem diversity is actually determined by differences in abiotic environmental factors, such as climate, soil, and water, which in turn create distinct habitats for species diversity not the other way around (Odum, 1993). A similar misconception was found in Statement 3, where 78.9% of students associated the formation of biomes with geographical-astronomical location while describing them using functional ecosystem components (producers-consumers-decomposers). These two conceptual errors in a single statement accepted by the majority of respondents indicate that the conceptual boundary between biomes and ecosystems is not clearly established within students' knowledge structures (Duit & Treagust, 2003).

Compared to previous research, similar misconceptions were found among regular biology students, but with a lower prevalence (around 61%) regarding the concept of the biodiversity hierarchy. The high prevalence among PGSD students in this study (84.2%) indicates that generalist programs such as PGSD result in a shallower understanding of ecological concepts compared to biology programs, consistent with the notion that the depth of knowledge content is directly proportional to the specificity of the program of study. Furthermore, the inconsistency between the simultaneous acceptance of Statement 1 (false) and Statement 13 (true) by the same students constitutes a manifestation of conceptual inconsistency (Novak, 2002) a condition in which two conflicting ideas are accepted without awareness of the contradiction, which can only be resolved through cognitive conflict explicitly designed into the learning process (Posner et al., 1982; Duit & Treagust, 2003).

The second finding of high scientific value is the identification of a failure in cross-concept knowledge transfer, which is most clearly evident in the contrast between Statement 7 and Statement 8. A total of 76.3% of students correctly understood that the climate stability of tropical rainforests supports high species diversity (P8), yet simultaneously 55.3% accepted the erroneous claim that the tundra has high biodiversity due to its abundant rainfall (P7). In fact, the tundra is the biome with the lowest precipitation (< 250 mm/year), is dominated by permafrost, and is the biome with the least biodiversity on Earth (Archibold, 1995; Chapin et al., 2002). Students with accurate knowledge of tropical forests should be able to apply the same principle that extreme climatic conditions result in low biodiversity to refute claims about the tundra. This failure reflects context-specific rote learning rather than transferable conceptual understanding (Mayer, 2002).

This phenomenon can theoretically be explained through the framework of "inert knowledge" (Whitehead, 1929), updated by Perkins & Grotzer (2005) knowledge that is "stored" but not "active" for use in new contexts. In contrast to the findings of Grotzer & Basca (2003), who found that students generally fail to understand complex causality in ecosystems, this study found that PGSD students can understand simple causal relationships (climate → biodiversity) but fail in reverse causal inference (extreme climate → low biodiversity). This is a crucial distinction in the findings: the issue lies not in the understanding of basic causality, but in the underdeveloped ability for higher-order inferential reasoning (Anderson & Krathwohl, 2001; Bloom et al., 1956).

The third finding with the most significant socio-ecological implications is a misconception rooted in the common belief about nature's resilience. As many as 52.6% of students accepted the claim that poaching does not disrupt ecosystems because populations can recover on their own (P19), and the same proportion accepted the claim that discharging waste into water bodies has no effect on aquatic habitats (P20). Both of these statements are ecologically incorrect: hunting that exceeds the population's reproduction rate triggers a trophic cascade that systematically collapses food webs (Terborgh et al., 2001), while water pollution causes eutrophication and hypoxia that kill aquatic organisms (Carpenter et al., 1998; Smith & Smith, 2012). An ecosystem's capacity for recovery has a threshold known as the

ecological threshold (Holling, 1973; Walker et al., 2004)—once this threshold is crossed, the ecosystem can no longer return to its original state.

What distinguishes these findings from previous research is the characteristics of the respondents. Prokop & Tuncer (2010) found similar misconceptions among high school students, while this study reveals that these misconceptions persist into the university level among prospective teacher students even after they have taken basic science courses. This reinforces the argument that such misconceptions cannot be eliminated solely through the presentation of factual information but require affective interventions and direct empirical experiences that create cognitive dissonance with initial beliefs (Strike & Posner, 1992; Kellert, 1997). This also explains why phenomenon-based learning approaches have proven more effective in revising ecological misconceptions compared to conventional lecture approaches (Kinchin, 2011; Sadler, 2004).

Based on the three findings above, the identified misconceptions can be classified into four categories, as presented in Table 2. This classification is important because each category requires a different remediation strategy. Substitutional misconceptions require total conceptual reconstruction; partial misconceptions require contextual expansion and transfer practice; whereas general belief-based misconceptions require direct empirical confrontation (Duit & Treagust, 2003; Wandersee et al., 1994).

Table 2. Classification of Identified Misconception

Misconception Categories	Statement (No.)	% Agree (Incorrect)	Severity Level
Substitutional (incorrect concept replaces the correct one)	P1, P3, P7	84,2 – 55,3	High
Partial (cannot be transferred to a new context)	P7 vs P8, P12, P13	55,3 – 73,7	Moderate
Excessive resilience (ecological folk belief)	P19, P20	52,6 – 52,6	High
Causal aambiguity (misleading premise)	P18	73,7	Moderate

Note: The severity level is determined based on the percentage of acceptance of false statement and the degree of conflict with prevailing scientific concepts.

The results of this study provide a scientific contribution that differs from previous studies in two ways. First, previous studies such as Sudjana (2015) and Hartati et al. (2019) generally only identified the presence of misconceptions without classifying the underlying cognitive mechanisms. This study goes a step further by identifying three distinct mechanisms of misconception formation, each with different implications for remediation strategies. Second, this study specifically targets PGSD students, a group that is strategically important yet relatively under-researched compared to biology or regular science education students and found a higher prevalence of misconceptions compared to those groups, reinforcing the urgency of special attention to science content education within the PGSD curriculum (Ball et al., 2008; Loughran et al., 2006).

Collectively, the above findings indicate that the required interventions must go beyond merely informative approaches. The conceptual change strategy developed by Posner et al. (1982) requires four conditions for successful conceptual change: students must (1) feel dissatisfied with their old concept, (2) understand the new concept, (3) judge the new concept to be more reasonable, and (4) judge the new concept to be more productive. The findings of this study indicate that the first condition has not been met for the majority of students, as they are unaware of the inconsistencies in their own understanding. Therefore, a two-tier or three-tier diagnostic test needs to be integrated into the course to explicitly highlight these inconsistencies to students (Taber, 2009). Additionally, the use of case studies on the local Nias ecosystem which is familiar to students as residents of the Nias Islands has the potential to accelerate conceptual change due to its direct relevance to students' lived experiences, as demonstrated by Rustaman's (2011) research that local contextualization significantly enhances the effectiveness of science learning in the PGSD setting (Rustaman, 2011; Novak, 1998; Bybee, 1997).

Discussion

Based on the results of the questionnaire administered to PGSD students, the majority of respondents demonstrated a fairly good understanding of the basic concepts of ecosystem diversity and biomes. This is evident from the prevalence of answers consistent with scientific concepts across most of the measured indicators. Students were able to identify the relationship between biotic and abiotic components in ecosystems and understand that their interactions play a crucial role in maintaining environmental balance. This strong grasp of the basic concepts indicates that the ecology material previously studied has provided students with a sufficiently solid conceptual foundation.

Regarding ecosystem diversity, the majority of students understand that differences in environmental factors such as temperature, rainfall, soil type, and water availability can lead to the formation of various types of ecosystems. This finding indicates that students have been able to connect environmental conditions with the characteristics of the organisms living within them. This understanding is important because the concept of an ecosystem is one of the

fundamental concepts in ecological studies that serves as the foundation for biology and IPAS learning in elementary school.

The research results also indicate that most students understand the concept of a biome as a group of ecosystems sharing relatively similar climatic, vegetation, and organism characteristics. Students can distinguish several types of biomes based on their environmental characteristics, such as tropical rainforests, savannas, deserts, and tundras. This understanding demonstrates that students have the ability to link geographical conditions with the distribution of living organisms within a given region.

Nevertheless, the analysis still revealed misconceptions regarding certain indicators. One such misconception pertains to the characteristics of the tundra biome. Some students still believe that the tundra possesses high biodiversity of flora and fauna because it is located in an area with abundant water availability. In reality, scientifically, the tundra biome has a relatively low level of biodiversity due to extremely cold temperatures, permafrost, and a short growing season. This finding indicates that some students still struggle to understand the relationship between climatic conditions and the level of biodiversity in a biome.

Misconceptions were also found regarding the concept of ecosystem balance in relation to human activities. Some students still believe that hunting wild animals does not have a significant impact on ecosystems because animal populations can recover naturally. In reality, uncontrolled hunting can lead to population decline, disruption of the food chain, and even the extinction of certain species. These findings align with research by Jahidin and Rabani, which indicates that ecological concepts including conservation and ecosystems are topics prone to misconceptions due to a lack of understanding regarding the interconnections among ecological concepts.

Additionally, some students provided inaccurate responses to statements regarding the impacts of environmental pollution. Some respondents believe that discharging waste into water bodies does not significantly affect the lives of aquatic organisms. In reality, water pollution can lead to a decline in habitat quality, disruption of the food chain, and a reduction in organism diversity within an ecosystem. This misunderstanding indicates that students have not fully grasped the relationship between human activities and environmental sustainability.

The emergence of misconceptions among students can be influenced by various factors. These factors include inadequate prior knowledge, inaccurate learning resources, teaching methods that are overly focused on rote memorization, and daily experiences that do not align with scientific concepts. Research by Purwanti and Kuntjoro found that misconceptions regarding ecological concepts can be attributed to students, textbooks, learning materials, teachers, teaching methods, and the learning context employed.

These findings also reinforce the view that misconceptions that are not promptly identified can develop into more complex conceptual errors. Conceptual errors among pre-service teachers are a major concern because they have the potential to be passed on to students when they teach in schools. Therefore, misconceptions need to be identified periodically so that instructors can design learning strategies capable of improving students' understanding before those concepts are taught to students.

Overall, the research results indicate that PGSD students already possess a fairly good understanding of the material on ecosystem diversity and biomes; however, some misconceptions were still found regarding specific concepts. Therefore, improvement efforts are needed through inquiry-based learning, the use of visual media, field observation activities, and conceptual discussions that can help students build a deeper scientific understanding. Consequently, the quality of concept understanding among these students as prospective elementary school teachers can be improved, and the risk of spreading misconceptions to their students can be minimized.

Conclusion

This study indicates that PGSD still hold misconceptions regarding several key concepts in the subject matter of biome and ecosystem diversity. The most prevalent misconceptions were found in the concepts of the relationship between ecosystem diversity and genetic and species diversity, the concept of biomes and their constituent components, the characteristics of the tundra biome, and the impact of human activities on ecosystem balance. These findings indicate that some students are not yet able to accurately distinguish between the concepts of biomes and ecosystems and do not fully understand the cause-and-effect relationships within ecological systems.

This study contributes to the field of science education by identifying patterns of misconceptions held by prospective elementary school teachers, thereby providing a foundation for the development of more effective teaching strategies. The results of the study indicate the need to implement conceptual change-based learning, the use of diagnostic instruments for misconceptions, and the utilization of real-world environmental phenomena to strengthen students' conceptual understanding. Further research is recommended to test the effectiveness of various learning models in reducing misconceptions regarding the diversity of biomes and ecosystems.

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AI Declaration

The authors declare that Artificial Intelligence (AI) tools were used during the preparation of this manuscript. ChatGPT, Claude AI, and Quillbot was utilized to assist with language translation, grammar checking, sentence editing, and manuscript structuring. AI was used exclusively as awriting support tool and did not contribute to the generation of research data, data analysis, interpretation of findings, or scientific conclusions. All outputs generated by AI were critically evaluated, verified, and edited by the authors. The authors remain fully responsible for the originality, accuracy, integrity, and scholarly content of this manuscript.

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