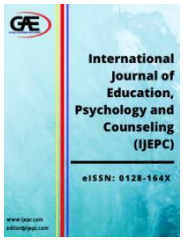
International Journal of Education, Psychology and Counseling
IJEPC
EISSN : 0128-164X
Volume 11 Issue 64 (September 2026) PP. 375-391



INTERNATIONAL JOURNAL OF EDUCATION, PSYCHOLOGY AND COUNSELLING (IJEPC)
https://gaexcellence.com/ijepc

EXPLORING GENERATIVE AI IN LEARNING BIOLOGICAL DIVERSITY: PERSPECTIVES OF PRE-SERVICE SCIENCE TEACHERS

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Article Info:

Article history:
Received date: 16.07.2026
Revised date: 30.07.2026
Accepted date: 20.08.2026
Published date: 07.09.2026

To cite this document:

Hamzah, A. A. (2026). Exploring Generative AI in Learning Biological Diversity: Perspectives of Pre-Service Science Teachers. *International Journal of Education, Psychology and Counselling, 11*(64), 375-391.

Abstract:

This study investigated the patterns of use, pedagogical roles, challenges, and ethical considerations of generative artificial intelligence (GenAI) among pre-service science teachers in learning Biological Diversity. A mixed-method case study design was conducted involving 15 Year 1 pre-service science teachers enrolled in a 14-week course at the Institute of Teacher Education, Penang Campus, Malaysia. Data were collected via an electronic mixed-method questionnaire comprising 5-point Likert scale items and open-ended questions. Quantitative data were analysed using descriptive statistics, while qualitative responses were analysed using thematic analysis. Results showed universal GenAI adoption (100%), with ChatGPT identified as the primary tool (100%) alongside Google Gemini (73.3%). Participants predominantly used GenAI for speciation understanding ($M = 4.47$), concept explanation ($M = 4.40$), and taxonomy classification ($M = 4.33$). Highly positive perceptions were reported regarding GenAI's role in connecting real-world issues, simplifying complex concepts, and aiding self-paced learning. However, major challenges included concerns over scientific accuracy ($M = 3.93$), potential over-reliance reducing independent thinking ($M = 4.27$), and over-simplification of technical procedural knowledge. Consequently, 100% of participants reported actively verifying AI outputs against textbooks and scientific literature. The study concludes that while GenAI is a valuable supplementary tool for biological diversity education, its successful implementation requires guided instruction that prioritizes epistemic vigilance, critical thinking, and ethical AI literacy.

International Journal of Education, Psychology and Counseling
IJEPC
EISSN : 0128-164X
Volume 11 Issue 64 (September 2026) PP. 375-391

DOI: 10.35631/IJEPC.1164018

Keyword:
AI Literacy, Biological Diversity, Epistemic Vigilance, Generative Artificial Intelligence (Genai), Pre-Service Science Teachers, Science Education

Introduction

The rapid advancement of generative artificial intelligence (GenAI) is reshaping education by offering new ways to support teaching and learning, particularly in biology disciplines. Tools such as ChatGPT and Google Gemini are increasingly used to enhance conceptual understanding, provide explanations, and support independent inquiry among learners. In biology education, where abstract concepts such as biological diversity, including classification, genetic variation, and ecological interactions, are often challenging, GenAI can serve as a cognitive support tool that improves accessibility and engagement. However, while GenAI presents significant pedagogical opportunities, its use also raises concerns regarding accuracy, over-reliance, and ethical considerations in academic settings (Kasneci et al., 2023; UNESCO, 2023; Deng et al., 2024). For pre-service science teachers, these issues are particularly important as their experiences with AI tools during training may influence their future classroom practices and instructional decisions (Krause et al., 2025). Understanding their perspectives is therefore essential in guiding effective and responsible integration of GenAI in science teacher education. This study aims to address the following research objectives:

RO1: To explore the patterns and purposes of generative AI use among pre-service science teachers in learning biological diversity.
RO2: To investigate pre-service science teachers' perceptions regarding the role of generative AI in supporting learning in Biological Diversity.
RO3: To investigate pre-service science teachers' perceptions of the challenges and ethical considerations associated with using generative AI in learning biological diversity.

Literature Review

Generative artificial intelligence (GenAI) has rapidly become part of higher education learning environments, particularly through conversational tools such as ChatGPT and Google Gemini. These technologies allow learners to generate explanations, summaries, examples, feedback, and responses to complex questions through interactive dialogue. Existing studies suggest that university students use GenAI for multiple academic purposes, including information seeking, clarification of difficult concepts, idea generation, writing support, and independent learning (Chan & Hu, 2023; Crompton & Burke, 2023; Kasneci et al., 2023). Unlike conventional information-search systems, GenAI can provide personalised and iterative responses based on

learners' prompts, potentially allowing students to explore academic concepts at their own pace. However, the educational value of GenAI depends not simply on access to the technology but on how learners critically evaluate and integrate AI-generated information into their learning processes.

Within science education, GenAI has particular potential because science learning frequently involves abstract concepts, specialised terminology, multiple levels of representation, and complex relationships between scientific phenomena. GenAI can support learners by providing simplified explanations, generating relevant examples, organising scientific information, and responding to follow-up questions. Research indicates that AI-based tools can function as cognitive scaffolds that help students interpret complex scientific ideas and engage more actively with learning content (Almasri, 2024; Kasneci et al., 2023). Such support may be particularly useful when students need clarification beyond scheduled classroom instruction. Nevertheless, science education also requires accurate disciplinary knowledge, evidence-based reasoning, observation, experimentation, and evaluation of scientific claims. Consequently, GenAI should be regarded as a supplementary learning resource rather than an authoritative source of scientific knowledge.

The issue is especially important in pre-service teacher education. Pre-service teachers are not only learners who use GenAI to support their current academic activities but are also future educators who may subsequently incorporate AI tools into classroom instruction. Studies indicate that pre-service teachers use GenAI to clarify subject knowledge, generate learning materials, support lesson preparation, obtain explanations, and explore alternative ways of presenting academic content (Nyaaba et al., 2024; Spasopoulos et al., 2025; Wang et al., 2025). Their experiences with GenAI during teacher preparation may therefore influence their future pedagogical decisions and approaches to technology integration. For this reason, understanding how pre-service teachers use, evaluate, and respond to GenAI is important for developing both pedagogical competence and AI literacy within teacher education programmes.

Biological Diversity provides a particularly relevant disciplinary context for examining these practices. Learning biological diversity requires students to understand interconnected concepts such as taxonomy, species classification, speciation, genetic variation, organismal diversity, ecological relationships, biodiversity indices, conservation, and biotechnology. Some of these concepts involve considerable terminology and conceptual complexity, creating potential challenges for novice learners. GenAI may support learning by explaining unfamiliar terminology, comparing biological groups, organising taxonomic information, illustrating relationships among concepts, and connecting scientific principles with environmental and conservation issues. Nyaaba et al. (2024), for example, identified the potential of GenAI as a learning assistant among pre-service teachers, while broader research in science education suggests that personalised explanations and interactive questioning can support engagement with complex subject matter. Nevertheless, empirical evidence focusing specifically on how pre-service science teachers use GenAI to learn Biological Diversity remains limited.

Despite these pedagogical opportunities, GenAI introduces substantial epistemic and educational challenges. One major concern is the scientific accuracy of AI-generated information. Large language models may generate responses that appear plausible and authoritative despite containing inaccurate, incomplete, outdated, or fabricated information (Kasneci et al., 2023). This issue is particularly significant in science education, where

conceptual precision and evidence-based reasoning are essential. Students must therefore develop epistemic vigilance by comparing AI-generated information with textbooks, peer-reviewed literature, lecturer guidance, and other authoritative scientific sources. Over-reliance on GenAI also raises concerns that students may become less inclined to independently analyse information, solve problems, or critically evaluate competing explanations. Systematic reviews of educational uses of ChatGPT similarly highlight concerns regarding excessive dependence on AI and its possible implications for students' critical thinking and autonomous learning (Albadarin et al., 2024).

Ethical considerations further complicate GenAI integration in teacher education. Academic integrity, transparency regarding AI-assisted work, authorship, plagiarism, data privacy, algorithmic bias, and responsible attribution have become important concerns as students increasingly use AI-generated material in academic tasks (Albadarin et al., 2024; Porayska-Pomsta et al., 2024; Rahmawati et al., 2025). These concerns are particularly relevant to pre-service teachers because they will eventually be expected to model responsible technology use and guide their own students in evaluating AI-generated information. Accordingly, AI literacy in teacher education should extend beyond technical ability to operate GenAI tools. It should include the capacity to evaluate scientific accuracy, recognise uncertainty and bias, verify information, understand ethical boundaries, and make informed decisions about when AI should or should not be used.

Although the broader literature on GenAI in higher education is expanding rapidly, several gaps remain. First, much of the existing literature examines university students across general academic contexts rather than discipline-specific learning. Second, emerging research on GenAI in teacher education often focuses on general perceptions, lesson preparation, or technological acceptance rather than how pre-service teachers use GenAI to understand specific scientific content. Third, relatively limited empirical attention has been given to Biological Diversity, despite the conceptual complexity of topics such as taxonomy, genetic diversity, speciation, biodiversity conservation, and biotechnology. Finally, pedagogical benefits, epistemic challenges, and ethical considerations are frequently examined separately, providing limited understanding of how these dimensions coexist within authentic learning contexts.

Therefore, the present study addresses this gap by examining GenAI use specifically among pre-service science teachers learning Biological Diversity within a Malaysian teacher education context. Rather than focusing only on whether students accept or intend to use GenAI, the study investigates three interconnected dimensions: (1) patterns and purposes of GenAI use, (2) perceived roles of GenAI in supporting Biological Diversity learning, and (3) perceived challenges and ethical considerations associated with its use. This disciplinary and contextual focus contributes to the emerging literature on GenAI in science teacher education by providing evidence about how future science teachers engage with GenAI as a learning resource while simultaneously negotiating issues of scientific accuracy, independent thinking, verification, and responsible AI use.

International Journal of Education, Psychology and Counseling
IJEPC
EISSN : 0128-164X
Volume 11 Issue 64 (September 2026) PP. 375-391

Methodology

Research Design and Study Context

This study adopted an embedded mixed-method case study design to explore how pre-service science teachers use and perceive generative artificial intelligence (GenAI) in learning Biological Diversity. The case study approach was selected because the investigation focused on a clearly bounded educational context involving one cohort of Year 1 pre-service science teachers enrolled in a 14-week Biological Diversity course at the Institute of Teacher Education, Penang Campus (IPGKPP), Malaysia. The bounded case enabled an in-depth examination of students' GenAI practices, perceived learning support, challenges, and ethical considerations within their actual course context.

The mixed-method component involved the concurrent collection of quantitative and qualitative data through a single questionnaire. Quantitative responses provided descriptive information about patterns of GenAI use and participants' perceptions, while qualitative responses provided further explanations of their experiences and reasoning. The qualitative component was therefore embedded within the case study to complement and contextualise the quantitative findings rather than to function as a separate independent study. This approach was appropriate for the exploratory nature of the research because it enabled numerical patterns to be interpreted alongside participants' descriptions of how and why they used GenAI during Biological Diversity learning.

Participants and Sampling

The study involved 15 Year 1 pre-service science teachers enrolled in the 14-week Biological Diversity course at IPGKPP. Participants were selected using purposive sampling because they represented the specific group relevant to the research objectives and had direct experience of learning Biological Diversity within the study context. The sample was intentionally restricted to this bounded cohort rather than designed to represent the broader population of pre-service science teachers in Malaysia.

Accordingly, the findings should be interpreted as context-specific evidence from an exploratory case rather than as statistically generalisable findings. The small sample allowed closer examination of participants' experiences and perceptions but limits the extent to which the results can be extrapolated to students in other teacher education institutions, disciplines, or educational settings.

Research Instrument

Data were collected using an electronic mixed-method questionnaire adapted from Chan and Hu (2023) and contextualised to Biological Diversity learning. The instrument contained both closed-ended and open-ended items and was organised around three areas corresponding to the research objectives: (1) patterns and purposes of GenAI use in learning Biological Diversity, (2) perceptions of the role of GenAI in supporting conceptual understanding and learning, and (3) perceptions of challenges and ethical considerations associated with GenAI use.

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EISSN : 0128-164X
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The quantitative component included items addressing the use of GenAI tools such as ChatGPT and Google Gemini and their application to Biological Diversity topics, including concept explanation, speciation, taxonomy classification, plant and animal phyla, genetic diversity, biodiversity indices, biotechnology, conservation, and related scientific concepts. Perception items were rated using a 5-point Likert scale ranging from 1 (Strongly Disagree) to 5 (Strongly Agree).

Because several questionnaire items were contextualised specifically to Biological Diversity, the adaptation went beyond the general higher education context of the original questionnaire. The instrument therefore served primarily as a context-specific exploratory measure of participants reported GenAI practices and perceptions rather than as a direct replication of the original instrument.

The qualitative component consisted of open-ended questions that allowed participants to describe how GenAI supported their understanding of Biological Diversity, the challenges or limitations they encountered, the strategies they used to verify AI-generated information, and their views regarding responsible and ethical GenAI use. These responses provided explanatory evidence that complemented the quantitative results.

Data Collection and Ethical Considerations

Data were collected electronically through Google Forms during the Biological Diversity course. Prior to participation, students were informed of the purpose of the study and provided informed consent. Participation was voluntary, and responses were collected anonymously to protect participants' identities and encourage candid responses.

The study was conducted in accordance with relevant ethical research requirements. The research procedures involving human participants were reviewed and approved by the Education Policy Planning and Research Division (EPRD), with approval reference IPGKPP.100-7/5 Jld 5(40). Participants were informed that the information collected would be used solely for academic and research purposes. Confidentiality and anonymity were maintained throughout data collection, analysis, and reporting.

Given that the participants were students within the institutional course context, particular attention was given to voluntary participation and confidentiality. No individually identifiable information is reported in the manuscript, and qualitative responses are presented without identifying individual participants.

Quantitative Data Analysis

Quantitative data were analysed using descriptive statistics, consistent with the exploratory nature of the case study and the small sample size. Frequencies and percentages were used to describe patterns of GenAI adoption and the types of GenAI tools used. Mean and standard deviation values were calculated for Likert-scale items to summarise participants' reported purposes of GenAI use, perceived learning support, and perceptions of challenges and ethical considerations.

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EISSN : 0128-164X
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No inferential statistical analysis was conducted because the purpose of the study was not to test population-level hypotheses or establish causal relationships. Instead, the quantitative analysis was intended to describe patterns within the bounded group of 15 participants. Frequencies were considered alongside percentages to ensure that findings were interpreted appropriately given the small sample.

Qualitative Data Analysis

Responses to the open-ended questions were analysed using the thematic analysis procedures described by Braun and Clarke (2006). The analysis involved familiarisation with participants' responses, initial coding of meaningful statements, grouping related codes into categories, reviewing recurring patterns, and developing broader themes that represented participants' experiences with GenAI.

The analysis focused on recurring patterns related to the ways GenAI supported Biological Diversity learning, perceived limitations of AI-generated scientific information, information-verification practices, independent and critical thinking, and responsible and ethical use. Theme frequencies were also recorded to indicate how commonly particular experiences were expressed within the group. However, these frequencies were used descriptively and were not treated as inferential evidence.

Representative participant responses should be presented together with the identified themes to demonstrate how the thematic interpretations were grounded in the qualitative data. Participant identifiers such as P1, P2, and P3 may be used while maintaining anonymity.

Integration of Quantitative and Qualitative Findings

Integration occurred during the interpretation of the findings. Rather than treating the two forms of data independently, qualitative responses were used to complement, explain, and contextualise patterns identified in the quantitative results. For example, high quantitative ratings regarding GenAI support for conceptual understanding were considered together with qualitative themes concerning conceptual simplification, real-world examples, interactive learning, and knowledge organisation. Similarly, quantitative concerns regarding scientific accuracy and over-reliance were interpreted alongside qualitative descriptions of inaccurate information, oversimplification, verification practices, and concerns about independent thinking.

This integrated approach provided a more comprehensive account of GenAI use within the bounded Biological Diversity learning context. Nevertheless, because both quantitative and qualitative data were obtained from the same small group through the same questionnaire, the integration is interpreted as complementarity and convergence of evidence rather than strong methodological triangulation.

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Results And Discussion

Patterns and Purposes of Generative AI Use in Learning Biological Diversity

Table 1 presents the patterns of generative AI use among pre-service science teachers in learning biological diversity. The findings show that all respondents (N = 15; 100%) reported having used artificial intelligence (AI) tools for learning biology topics, indicating universal exposure to AI-based learning support among the participants. In terms of specific applications, ChatGPT was the most widely used generative AI tool, with all respondents (100%) reporting its use for learning biological diversity concepts. Google Gemini was also commonly used, with 73.3% (n = 11) of respondents indicating its use. In addition, a small proportion of respondents (13.3%, n = 2) reported using other AI tools besides ChatGPT and Google Gemini. Thus, the findings indicate a strong reliance on generative AI tools, particularly ChatGPT, as a primary digital learning support. This suggests that generative AI has become an integrated component of pre-service science teachers' learning practices in biological diversity.

Table 1: Patterns Of Generative AI Use In Learning Biological Diversity

Item	Frequency (N)	Percentage (%)
AI use in learning biology topic	15	100%
Generative AI chatbots used: -		
ChatGPT	15	100%
-Google Gemini	11	73.30%
-Others	2	13.30%

Table 2 presents the purposes of generative AI use in learning biological diversity concepts. The results show that pre-service science teachers reported a high level of use across all listed learning purposes, with an overall mean score of M = 4.36. All items recorded mean values above 4.20, indicating strong agreement among respondents regarding the use of generative AI for various biological diversity learning tasks. Among the purposes listed, items B2 (speciation understanding) recorded the highest mean (M = 4.47, SD = 0.74), suggesting that generative AI was most frequently used to support understanding of speciation concepts.

This was followed by B1 (concept explanation), which also showed a high mean score (M = 4.40, SD = 0.63), indicating that generative AI was commonly used to clarify complex biological diversity concepts. Items related to taxonomy classification, phyla (plants and animals), genetic diversity, and biodiversity indices (B3–B6) also showed consistently high mean values ranging from M = 4.27 to 4.33, reflecting the broad use of generative AI across multiple biological diversity topics. The relatively low standard deviation values (SD = 0.62–0.74) indicate a consistent pattern of responses among participants.

Table 2: Purposes Of Generative AI Use In Learning Biological Diversity.

Item	Statement	Mean	SD
B1	Concept explanation	4.40	0.63
B2	Speciation understanding	4.47	0.74
B3	Taxonomy classification	4.33	0.62
B4	Phyla (plants & animals) learning	4.33	0.72

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B5	Genetic diversity understanding	4.33	0.72
B6	Biodiversity indices interpretation	4.27	0.70

The findings indicate that generative AI tools, particularly ChatGPT, have become increasingly integrated into the learning practices of pre-service science teachers in Biological Diversity. The universal use of AI tools among participants suggests that students rely on generative AI to support understanding of complex biology concepts through personalised explanations and interactive learning support. The high mean scores for concept explanation and speciation understanding further demonstrate that AI tools are frequently used to simplify abstract and conceptually challenging topics. These findings are consistent with previous studies which reported that generative AI can enhance conceptual understanding, independent learning, and student engagement in science education (Kasneci et al., 2023; Lo, 2023; Tlili et al., 2023). Overall, the findings suggest that generative AI functions as an important supplementary learning tool in Biological Diversity learning among pre-service science teachers.

Perceived Role of Generative AI in Supporting Learning in Biological Diversity

Table 3 shows that pre-service science teachers held generally highly positive perceptions of generative AI in supporting learning in Biological Diversity. All items recorded high mean scores ranging from M = 4.27 to 4.60, indicating strong agreement across participants. The highest mean score was recorded for analysis of biodiversity conservation strategies (D5; M = 4.60, SD = 0.51). High mean scores were also observed for understanding genetic variation, biotechnology applications, and organism morphology (C3, C5, D1; M = 4.53). Other items similarly indicated strong perceptions of AI support in enhancing conceptual understanding, environmental issue analysis, case study interpretation, and integration of theoretical and practical biodiversity knowledge. Although understanding DNA techniques (D4; M = 4.27, SD = 0.46) recorded the lowest mean score, it still reflected a high level of agreement. Overall, low standard deviations (SD = 0.46–0.74) suggest consistent perceptions among respondents.

Table 3: Perceptions Of Generative AI In Support Of Learning

Item	Statement	Mean	SD
C1	AI explanations enhance understanding of speciation concepts	4.40	0.51
C2	AI tools help connect biological diversity concepts with real-world environmental issues	4.47	0.64
C3	AI tools support understanding of genetic variation in populations	4.53	0.52
C4	AI tools assist understanding of factors threatening genetic diversity	4.33	0.62
C5	AI tools facilitate understanding of biotechnology applications in biodiversity conservation	4.53	0.52
C6	AI tools make learning biological diversity more engaging.	4.40	0.63
D1	AI tools support understanding of morphology in plant and animal groups	4.53	0.52
D2	AI tools assist analysis of biodiversity case studies	4.47	0.52

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D3	AI tools support interpretation of genetic diversity concepts (allele frequency, heterozygosity)	4.4	0.51
D4	AI tools facilitate understanding of DNA techniques (electrophoresis, sequencing)	4.27	0.46
D5	AI tools support analysis of biodiversity conservation strategies	4.60	0.51
F1	AI tools improve understanding of threats to genetic diversity (bottleneck effect, inbreeding depression, habitat destruction)	4.47	0.64
F2	AI tools support analysis of human impacts on biodiversity	4.4	0.63
F3	AI tools assist understanding of diseases affecting biodiversity (epidemic, endemic, pandemic)	4.4	0.74
F4	AI tools enhance understanding of biotechnology applications in conservation (stem cell research, DNA cloning, gene therapy, metagenomics)	4.33	0.72
F5	AI tools support understanding of bioethics, legislation, and international statutes	4.47	0.64
F6	AI tools help connect theoretical and practical biodiversity concepts	4.47	0.64

The qualitative findings from the respondents reveal four major themes regarding '*How generative AI tools support understanding of biological diversity concepts*': (1) conceptual simplification, (2) provision of examples and real-world connections, (3) interactive and self-paced learning support, and (4) visualisation and knowledge organisation. The dominant theme was conceptual simplification (N = 11), where the pre-service science teachers reported that AI helped break down complex concepts such as genetic diversity, taxonomy, and speciation into simpler explanations. Another theme was real-world application (N = 9), where AI supported understanding through examples and links to environmental issues. Participants also highlighted interactive and self-paced learning (N = 7), particularly the ability to ask follow-up questions and receive immediate clarification. Finally, visualisation and knowledge organisation (N = 6) showed that AI-generated diagrams, summaries, and structured notes supported comprehension and retention of biological diversity concepts.

The findings indicate that pre-service science teachers perceive generative AI as a highly effective tool for supporting learning in Biological Diversity, particularly in enhancing conceptual understanding, contextual learning, and analytical thinking. This aligns with recent literature suggesting that generative AI tools such as large language models can function as cognitive scaffolds that support explanation, clarification, and knowledge construction in education (Kasneci et al., 2023). The high perceived usefulness in simplifying complex biological concepts supports the view that AI can reduce cognitive load by translating abstract scientific ideas into more accessible language. This is consistent with UNESCO (2023), which emphasises that generative AI can support personalised explanations and adaptive learning experiences, particularly in complex subject domains such as science education.

Furthermore, the qualitative findings show that AI enhances contextual and real-world learning, particularly in linking biodiversity concepts with environmental issues and conservation strategies. This reflects AI's role in supporting higher-order cognitive organisation, particularly in structuring scientific explanations and argumentation. This supports Dwivedi et al. (2023), who argue that generative AI expands learning opportunities

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by enabling contextualised knowledge generation and applied understanding across disciplines. The interactive nature of AI, where learners can ask questions and receive immediate feedback, also reflects its potential as a self-regulated learning tool. This aligns with Kasneci et al. (2023), who highlight that AI-based systems can promote learner autonomy by supporting iterative questioning and adaptive explanation.

However, despite the overall positive ratings, the relatively lower mean for understanding DNA techniques suggests that AI may still have limitations in supporting highly technical procedural knowledge. This implies that while generative AI is effective for conceptual and interpretive learning, it should be complemented with hands-on laboratory instruction for procedural scientific skills. Overall, the findings reinforce the growing consensus that generative AI is a promising educational tool in science education, but its effectiveness depends on thoughtful integration into pedagogy rather than replacement of traditional learning methods (UNESCO, 2023; Dwivedi et al., 2023).

Perceived Challenges and Ethical Considerations Associated with Using Generative AI In Learning Biological Diversity

The findings indicate that pre-service science teachers demonstrate a generally high awareness of both the challenges and ethical considerations associated with the use of generative artificial intelligence (AI) in learning biological diversity. Quantitative results show moderate to high agreement across all items (M = 3.93–4.40), with relatively low standard deviations, suggesting consistent perceptions among respondents as in Table 4. Overall, participants recognise both the educational value and limitations of AI, particularly in relation to scientific accuracy, critical evaluation, and ethical responsibility.

Table 4: Challenges And Ethical Considerations Associated in The Use of Generative AI For Biodiversity Learning

Item	Statement	Mean	SD
E1	AI sometimes provides inaccurate biological information	3.93	0.70
E2	Difficulty determining reliability of AI-generated information	4.07	0.73
E3	Over-reliance on AI may reduce independent thinking	4.27	0.70
E4	Need to verify AI responses using textbooks or scientific sources	4.33	0.62
G1	AI increases awareness of ethical issues in biodiversity conservation	4.40	0.63
G2	AI encourages critical evaluation rather than blind acceptance	4.40	0.73
G3	I feel confident assessing scientific accuracy of AI information	4.07	0.70
G4	AI supports understanding of global responsibility in biodiversity protection	4.33	0.62
G5	AI encourages consideration of bioethical implications in biotechnology	4.27	0.70

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EISSN : 0128-164X
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The results show that the most prominent concern among participants is the need to verify AI-generated information using authoritative scientific sources (M = 4.33). This reflects strong academic caution and aligns with concerns raised in recent studies that generative AI may produce plausible but inaccurate scientific explanations, requiring users to critically validate outputs (Kasneci et al., 2023; Lee & Zhai 2024). Similarly, participants expressed concerns about over-reliance on AI potentially reducing independent thinking (M = 4.27), highlighting awareness of cognitive dependency risks frequently reported in educational AI literature (Holmes et al., 2022).

Qualitative Findings on Challenges, Verification Practices, and Responsible GenAI Use

The thematic analysis of responses to the open-ended question, *"What challenges or limitations have you encountered while using AI tools in this course?"*, identified four recurring themes: (1) inaccuracies in AI-generated scientific information, (2) oversimplification of complex biological concepts, (3) the need for continuous information verification, and (4) concerns regarding reduced independent and critical thinking. Inaccuracies in AI-generated content emerged as the most frequently reported challenge (n = 13), followed by the need for continuous verification (n = 12), oversimplification of complex biological concepts (n = 10), and concerns about reduced independent and critical thinking (n = 9). These frequencies indicate the recurrence of particular experiences within this bounded group of participants and should not be interpreted as estimates of prevalence among pre-service science teachers more broadly.

The first theme concerned the accuracy and scientific reliability of AI-generated information. Participants indicated that GenAI responses were not consistently regarded as sufficiently accurate or precise for academic use, particularly when dealing with specialised Biological Diversity content. A related concern involved the oversimplification of complex concepts, where AI-generated explanations were perceived as useful for obtaining an initial understanding but sometimes lacked the depth, precision, or disciplinary detail required for scientific learning. These findings are consistent with previous concerns that generative AI may produce plausible but inaccurate information or simplify disciplinary knowledge in ways that obscure scientific complexity (Bender et al., 2021; Lund & Wang, 2023). Within the context of the present study, the findings suggest that participants did not necessarily regard GenAI as an authoritative scientific source, but rather as a supplementary tool whose outputs required further evaluation.

A closely related theme concerned verification and epistemic vigilance. All 15 participants reported verifying AI-generated information through other sources, including textbooks, lecture notes, scientific journals, credible online resources, and, when necessary, consultation with lecturers or peers. Participants therefore appeared to employ multi-source verification strategies rather than accepting GenAI responses without further scrutiny. This pattern is consistent with the quantitative result showing strong agreement with the need to verify AI-generated responses using textbooks or scientific sources (M = 4.33). The convergence between the quantitative and qualitative findings indicates that verification was an important feature of how participants engaged with GenAI. Rather than demonstrating fully developed information literacy, the findings more cautiously suggest an emerging awareness of the need to assess the credibility and scientific accuracy of AI-generated information. Such practices are particularly

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EISSN : 0128-164X
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important in science education because GenAI-generated explanations may contain factual inaccuracies, incomplete reasoning, or unsupported claims (Cotton et al., 2024).

The fourth theme involved concerns about independent and critical thinking. Nine participants indicated that excessive dependence on GenAI could potentially reduce opportunities to think independently, construct explanations, or solve problems without technological assistance. This finding complemented the quantitative result for the statement that over-reliance on AI may reduce independent thinking (M = 4.27). Participants therefore appeared to recognise a distinction between using GenAI as learning support and becoming dependent on it as a substitute for personal reasoning. This concern is important in Biological Diversity learning, where students are expected not only to retrieve scientific information but also to classify, compare, interpret, evaluate, and apply biological concepts. The findings therefore reinforce the importance of incorporating GenAI in ways that preserve active scientific reasoning rather than replacing it.

The qualitative responses also revealed a strong preference for guided and responsible integration of GenAI. All participants (n = 15) indicated that GenAI should be used as a supplementary learning resource rather than as a replacement for lecturers, textbooks, or other authoritative scientific sources. Participants also identified benefits associated with conceptual understanding (n = 13), particularly when GenAI was used to explain abstract biological processes and biodiversity-related concepts. Personalised and self-paced learning emerged as another perceived benefit (n = 11), while nine participants referred to efficiency-related advantages, such as obtaining information and explanations more quickly. These findings should be interpreted as participants' perceptions of GenAI usefulness rather than evidence that GenAI objectively improves learning efficiency or academic achievement.

The qualitative findings were also consistent with participants' responses regarding ethical and responsible AI use. Quantitative results showed strong agreement that GenAI could promote awareness of ethical issues related to biodiversity conservation (M = 4.40) and encourage critical evaluation rather than unquestioning acceptance of information (M = 4.40). Participants also perceived GenAI as supporting consideration of global responsibility in biodiversity protection (M = 4.33) and bioethical implications associated with biotechnology (M = 4.27). When interpreted alongside participants' reported verification practices, these findings suggest that responsible GenAI use may involve more than technical competence. It also requires awareness of scientific credibility, ethical implications, limitations of AI-generated knowledge, and appropriate boundaries for its use. This interpretation is consistent with educational frameworks emphasising critical AI literacy, ethical reasoning, and human oversight in AI-supported learning (UNESCO, 2023).

Overall, the integration of the quantitative and qualitative evidence revealed a consistent pattern. Participants perceived GenAI as useful for supporting conceptual understanding, accessing explanations, and facilitating self-paced learning, while simultaneously recognising limitations related to scientific accuracy, oversimplification, cognitive dependence, and ethical responsibility. The findings therefore support a model of human-guided GenAI integration, in which AI serves as a supplementary cognitive resource rather than a replacement for lecturers, scientific literature, laboratory experiences, or independent reasoning. Within Biological Diversity education, effective use of GenAI should consequently emphasise verification of

scientific information, critical questioning of AI-generated responses, preservation of independent thinking, and explicit development of ethical AI literacy.

Conclusion

This study demonstrates that generative artificial intelligence has become an important supplementary learning tool among pre-service science teachers in learning Biological Diversity. The findings revealed that participants frequently use AI tools, particularly ChatGPT, to support conceptual understanding, problem-solving, and engagement with complex biodiversity topics. Participants generally perceived generative AI positively due to its ability to simplify scientific concepts, provide interactive and self-paced learning support, and connect theoretical knowledge with real-world applications. However, the study also identified important challenges related to information accuracy, over-reliance, and the need to verify information using credible scientific sources. Despite these concerns, the participants demonstrated awareness of ethical and critical evaluation practices when using AI. Overall, the findings suggest that generative AI has strong potential to enhance biology education when integrated responsibly through guided instruction that emphasises critical thinking, academic integrity, and ethical AI literacy.

Appreciation

I would like to express my sincere appreciation and gratitude to all Year 1 Science Education students at the Institute of Teacher Education, Penang Campus, for their valuable cooperation and active participation throughout the research process. I also wish to thank the institution for its continuous support and assistance in facilitating this study. Special thanks to my mother, Mrs. Farishah, for her constant encouragement, patience, and unwavering belief in me, especially during the most challenging times of this journey.

International Journal of Education, Psychology and Counseling
IJEPC
EISSN : 0128-164X
Volume 11 Issue 64 (September 2026) PP. 375-391

Acknowledgements: The author would like to express her sincere gratitude to the Institute of Teacher Education, Penang Campus, for providing the necessary resources and support throughout this research. Special appreciation is extended to all Year 1 Science Education students for their valuable cooperation and active participation during the research process, as well as colleagues and peers whose insights greatly enhanced the quality of this paper.

Funding Statement: No Funding

Conflict of Interest Statement: The authors declare that there is no conflict of interest regarding the publication of this paper. All authors have contributed to this work and approved the final version of the manuscript for submission to the International Journal of Education, Psychology and Counselling (IJEPC).

Ethics Statement: This study was conducted in accordance with ethical research standards. All procedures involving human participants were reviewed and approved by the Education Policy Planning and Research Division (EPRD), approval number IPGKPP.100-7/5 Jld 5(40). Informed consent was obtained from all participants prior to data collection. Participation was voluntary, and respondents were assured of confidentiality and anonymity. The data collected were used solely for academic purposes.

Author Contribution Statement: All authors contributed significantly to the development of this manuscript. Azlina binti Amir Hamzah was fully responsible for the conceptualization, methodology, and overall supervision of the study, handled data collection, analysis, and interpretation of results, contributed to the literature review, drafting, and critical revision of the manuscript. The author read and approved the final version of the manuscript prior to submission.

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