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Preservice Mathematics Teachers' Reflections on AI-Enhanced Lesson Exemplars for Promoting Environmental Stewardship

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Article Info

Abstract

Amid growing calls for sustainability education and the responsible use of artificial intelligence (AI) in schools, this study explores how preservice mathematics teachers reflect on the integration of AI tools in designing lesson exemplars that promote environmental stewardship. Anchored on reflective practice and contextual pedagogy, the study employed a qualitative approach through document and thematic analysis of group reflection journals written by fourth-year Bachelor of Secondary Education major in Mathematics students enrolled in an Environmental Science course. Their culminating task was to co-design AI-enhanced mathematics lesson exemplars with embedded environmental concepts such as climate change, pollution, biodiversity loss, and sustainable practices. The results revealed three key insights. First, preservice teachers employed diverse pedagogical strategies such as real-world contextualization, problem-based learning, and interactive tools, while aligning mathematical content (e.g., statistics, rational numbers, probability) with environmental themes. Second, reflections underscored AI's utility in content planning, generating ideas, and enhancing lesson efficiency, while emphasizing the need for localization, simplification, and ethical judgment. Third, challenges included adapting AI-generated materials to suit learners' contexts and ensuring the appropriateness and cultural relevance of examples. Participants demonstrated increasing awareness of ethical AI use and environmental responsibility. The study highlights the value of integrating interdisciplinary and sustainability-focused approaches in mathematics education through AI-supported lesson design. It also offers practical implications for teacher education programs to embed AI literacy, environmental education, and reflective pedagogy in preservice training. In doing so, the study contributes to the growing discourse on future-ready, ethically grounded, and socially responsive teacher preparation.

Introduction

In the 21st century, education has undergone a paradigm shift toward global sustainability, driven by rapid technological advancements and the imperative to cultivate responsible global citizenship. At the core of this transformation are the United Nations Sustainable Development Goals (SDGs), a set of 17 interconnected objectives launched in 2015 to guide equitable and inclusive progress worldwide. Chief among these is SDG 4 (Quality Education), which emphasizes inclusive and lifelong learning opportunities (Tang, 2015). Notably, SDG 4 intersects with SDG 13 (Climate Action), underscoring education's role in fostering environmental literacy, behavioral change, and sustainable practices (Bell, 2016; Singh et al., 2024). In this evolving context, mathematics education, which is traditionally framed around abstraction and procedural mastery, is being re-envisioned as a vehicle for environmental literacy and systems thinking (Meylani, 2025).

Historically, mathematics has often been taught devoid of context, with emphasis on algorithmic accuracy and procedural fluency. While such competencies remain essential, they are insufficient in addressing contemporary ecological challenges, which demand interdisciplinary thinking, moral responsibility, and problem-solving grounded in real-world issues. Integrating socially relevant socio-scientific concerns, particularly environmental stewardship, into mathematics curricula enables learners to analyze ecological systems, evaluate sustainability scenarios, and critically assess human impacts using mathematical tools (Silva & Groenwald, 2015; Karjanto, 2023; Routray & Mohanty, 2024). Activities such as statistical modeling of climate trends, algebraic optimization of land use, and sustainability-infused calculus applications exemplify how mathematics can be transformed into a purposeful lens for ecological inquiry (Pfaff et al., 2011; Milosh, 2017). Such infusion enriches learning with relevance, urgency, and ethical depth.

The success of this pedagogical transformation depends on preservice mathematics teachers, whose beliefs, practices, and pedagogical orientations are still developing. Their dispositions toward mathematics and sustainability directly shape future instructional practices (Su et al., 2023; Kanandjebo, 2024). However, the abstract nature of mathematics often poses barriers to its connection with real-world environmental issues. Thus, equipping future teachers with practical resources, contextual models, and opportunities for reflective thinking becomes essential (Moreno-Pino et al., 2022; Rafiq-uz-Zaman et al., 2024). Teacher education programs must respond through deliberate curriculum integration, experiential tasks, and access to authentic, interdisciplinary pedagogical tools.

A promising strategy lies in the use of lesson exemplars, which are structured, research-informed lesson plans that demonstrate how mathematics can be blended with sustainability themes. These exemplars support instructional design, facilitate pedagogical reflection, and provide concrete pathways to link environmental contexts with mathematical objectives (Su et al., 2023; Owens et al., 2019; Gürbüz & Çalik, 2021). They not only help preservice teachers conceptualize and practice interdisciplinary teaching but also offer models for situating math learning within socially meaningful and ecologically relevant issues.

The advent of artificial intelligence (AI) expands the capabilities of lesson exemplar development. AI-enhanced

lesson exemplars, supported by tools such as intelligent tutoring systems, generative platforms, and adaptive feedback systems, can scaffold planning, provide data visualizations, and simulate real-world ecological problems (Kaur et al., 2024; Tang, 2024; Talgatov et al., 2024). In mathematics education, such technologies support the creation of dynamic, differentiated, and inquiry-rich learning experiences. However, effective integration requires that preservice teachers develop both pedagogical and technological fluency, as well as ethical awareness of AI's limitations and possibilities (Young, 2024).

Reflective practice plays a central role in supporting this integration. Through reflection, preservice teachers examine their instructional strategies, student needs, and evolving teaching philosophies (Sharil & Kyriacou, 2015; Anand & Gangmei, 2023). In sustainability-focused and AI-enhanced contexts, reflection helps teachers consider not only instructional design, but also ecological relevance, ethical concerns, and technological appropriateness (Tatira, 2023). It also deepens metacognitive insight and supports alignment with broader educational and social goals (Kaminski, 2003; Hendriwanto, 2021).

Despite its promise, the integration of environmental sustainability and AI in mathematics education remains underexplored, particularly in developing countries such as the Philippines. Local teacher education institutions face challenges such as digital inequity, limited exposure to interdisciplinary planning, and fragmented curriculum support (Valencia, 2018; Bercasio & Remolacio, 2022; Quimat & Picardal, 2024). Little is known about how preservice mathematics teachers reflect on AI-supported lesson planning for sustainability or how they navigate ethical, pedagogical, and contextual complexities in low-resource settings. This study addresses this gap by exploring how preservice mathematics teachers engage with AI-enhanced lesson exemplars that promote environmental stewardship, with the aim of informing more responsive and future-oriented teacher education programs.

Related Literature and Studies

Reflections of Preservice Math Teachers

Reflection is a critical process in the identity formation and pedagogical growth of preservice mathematics teachers. Coddington and Swanson (2019) emphasize how contextualized early teaching experiences shape professional identity and instructional choices. Stoehr (2019) adds that community-based modules promote deeper engagement by connecting mathematics with students' lived experiences. Similarly, Cyrino (2018) shows that multimedia case reflections enhance pedagogical awareness and foster resilience. Kholid et al. (2021) categorize reflective thinking into clarification, connective, and productive forms, each essential for mathematical reasoning. Collaborative reflection, as Lee-Hassan (2020) notes, also encourages the reexamination of beliefs and nurtures an inclusive classroom culture. Collectively, these findings underscore that reflective practice is a dynamic and multifaceted process essential to the development of mathematics educators.

Lesson Exemplars with Environmental Stewardship

Incorporating environmental issues into mathematics instruction fosters both ecological literacy and critical

thinking. Dyusembina and Kanatkali (2023) demonstrates that embedding sustainability in mathematical problems enhances student engagement and ecological awareness. Kenschaft and Clark (2003) illustrate real-world environmental applications of mathematics, such as data analysis for pollution or resource use. Barwell (2018) promotes critical mathematics education as a means of addressing sustainability issues. Said et al. (2024) adds that integrating population growth, deforestation, and climate-related models into math lessons contextualizes learning. These studies affirm that environmentally focused math exemplars are not only feasible but transformative.

AI-Enhanced Mathematics Lesson Planning

Recent research reveals the pedagogical potential of AI in lesson design. Rizos et al. (2024) highlight how tools like ChatGPT support customized lesson planning, especially for learners with special needs. Ali (2024) shows how AI and computational thinking enhance students' conceptual grasp and engagement. Systematic reviews underscore AI's capacity to provide real-time feedback and personalized learning experiences. However, Maulida et al. (2024) caution that access and teacher training remain barriers. Dibaba et al. (2024) further advocate for lesson study models that empower teachers to critically evaluate and refine AI-driven instructional plans.

Integration with SDG Goals on Environmental Protection

Mathematics can play a pivotal role in environmental protection through education. Rafiq-uz-Zaman et al. (2024) find that integrating environmental content enhances both ecological awareness and problem-solving. Nugraheni (2024) stresses the relevance of mathematics in addressing climate threats. The Realistic Mathematics Education (RME) model has shown promise in grounding math instruction in everyday environmental problems (Maysun et al., 2023). Ariza and Olatunde-Aiyedun (2024) call for sustained teacher training to embed sustainability in STEM curricula. Meylani (2025) further emphasizes that such integration makes mathematics more relevant and engaging for learners.

Globally, teacher education programs are similarly rethinking mathematics instruction through sustainability and AI integration. Finland embeds environmental systems modeling to promote civic competence (Kotilainen & Saari, 2018), while Canada and Singapore emphasize AI literacy and critical evaluation as core competencies (Holmes et al., 2021; Chen et al., 2023). These international perspectives situate the present study within wider institutional shifts toward future-oriented, ethically grounded STEM education.

Despite increasing global advocacy for sustainability education and the rapid evolution of educational technologies, the integration of environmental stewardship into mathematics education remains a largely underexplored terrain, particularly through the lens of artificial intelligence (AI). While lesson exemplars offer structured and research-informed models for teaching, their potential is further amplified when enhanced by AI tools that provide personalized support, automate tasks, and simulate complex ecological systems. However, little is known about how preservice mathematics teachers reflect on and engage with such AI-enhanced exemplars to meaningfully integrate sustainability into their teaching practices. This gap is especially pronounced in low-

resource contexts like the Philippines, where digital inequities and fragmented curricular support pose significant challenges to innovation. Understanding how future educators perceive, internalize, and make pedagogical decisions around AI-enhanced, sustainability-driven lessons is critical to shaping teacher preparation programs that are both future-ready and socially responsive.

To address this gap, the present study investigates:

1. What technological and pedagogical strategies and content connections emerge from lesson exemplars that link mathematical concepts with environmental issues?
2. How do preservice mathematics teachers reflect on the use of AI-enhanced lesson exemplars in promoting environmental stewardship within mathematics education?
3. What challenges and opportunities do preservice teachers encounter when utilizing AI tools in lesson planning for environmental education?

Theoretical Framework

The framework of the current study is based on the fusion of these three learning theories: (1) Social Constructivism (Vygotsky, 1978), Self-Regulated Learning Theory (Zimmerman, 2002), and TPACK model (Mishra & Koehler, 2006). Such theoretical perspectives also offer a solid basis to explore how preservice mathematics teachers interact with AI-supported lesson examples to foster environmental awareness and environmental stewardship.

According to social constructivism, knowledge is co-constructed by social interaction, cultural tools, meaningful participation in relevant real-world contexts. In this perspective, AI-enhanced lesson exemplars are considered as the mediating tools to assist collaborative meaning-making and situated learning. Including real world environmental problems in a mathematics classroom would allow pre-service teachers to engage with more complex ideas which in turn would promote better understanding and context-dependent pedagogy to teach those ideas (Vygotsky, 1978; Kanandjebo, 2024). AI tools, whether generative platforms or adaptive systems, are more than mere technological aids, but cognitive partners that scaffold the teachers' zone of proximal development.

Self-Regulated Learning Theory, on the other hand, describes how students set goals, monitor performance, make attributions about the outcomes, and adjust strategies for improvement (Zimmerman, 2002). In this paper, the preservice teachers begin reflecting on the impact of AI inferred lesson exemplars on their pedagogical thinking and values. Reflection journals enable them to evaluate the effectiveness, appropriateness, and ethical implications of integrating AI and environmental themes in math lessons, thereby reinforcing metacognitive awareness and adaptive teaching behaviors (Siddiqui et al., 2020).

To these, the TPACK framework adds a perspective on the integral knowledge needed to teach well with technology. In particular, the preservice teachers involved in this study are working at the interface of technological knowledge (TK), pedagogical knowledge (PK), and content knowledge (CK) in the development and evaluation of AI-enhanced lesson exemplars. This paper examines how they create AI infused mathematics

lessons that are not only mapped to the curriculum standards, but also transverse environmental contexts and sustainable intentions (Chiu & Chai, 2020). In so doing, the framework describes the dynamic process used to make informed decisions about how to integrate emerging technology in meaningful and socially responsible pedagogical activities.

These theories both structure the research design and frame the analysis of how PSTs reflect on the pedagogical, technological, and ecological dimensions of their instructional planning. The intersection between social interaction, reflective agency and holistic knowledge systems provides the foundation for the conceptualization of teacher learning in the context of AI-enhanced, sustainability-oriented mathematics education.

Method

Research Design

Using a qualitative research design, this study investigated preservice secondary mathematics teachers' reflections on the use of AI-enhanced lesson exemplars in fostering environmental stewardship. Qualitative design is suitable for the study, as it is used for exploring the phenomenon and provides an in-depth analysis of the informants' lived experience, meaning construction, and interpretation (Creswell & Poth, 2018). It also supports the research objective of learning how preservice teachers are incorporating and critically engaging with new technologies and themes of sustainability when lesson planning.

Moreover, the study employed two related qualitative methods: document analysis and thematic analysis. AI-enhanced lesson exemplars by participants were subjected to document analysis allowing researchers to discover themes of instructional strategies, integration of environmental science concepts, and AI tool use (Bowen, 2009). These examples also functioned as genuine objects that revealed the ways in which the preservice teachers constructed the interconnections between mathematics, sustainability and technology.

Additionally, group reflection journals produced by the participants were analyzed using a thematic analysis approach (Braun & Clarke, 2006). This approach enabled us to identify common codes, categories and core themes around their experiences, challenges, ethical considerations and pedagogical insights developing AI-integrated, and environmentally contextualized math lessons. The combined use of document and thematic analyses allowed for an in-depth understanding of both instructional design outputs and reflective processes thus increasing the validity of the results.

Research Local and Participants

The study was implemented in a state university in the Philippines, specifically among forty-six fourth year Bachelor of Secondary Education (BSEd) major in mathematics students who were enrolled in Environmental Science. This purposefully selected group was targeted because of its unique placement at the intersection of mathematics education and environmental literacy where the context was appropriate to explore the interdisciplinary pedagogical link. Participation formed part of a required culminating task in the Environmental

Science course. Group formation followed a stratified assignment based on AI familiarity and prior academic performance, creating balanced teams and enabling diverse competencies to influence lesson outcomes.

As preservice mathematics teachers are approaching the end of their course of study, these students were using critical and lesson planning strategies to integrate their pedagogical content knowledge with their content knowledge and awareness of sustainability issues. Their enrollment in the Environmental Science course during the semester of data collection also prepared them in teaching-related competencies related to the content knowledge of the broader environmental issues that would enable them to develop, implement, and critically reflect on AI-enhanced lesson exemplars designed to infuse environmental stewardship in mathematics instruction.

Participants were purposefully selected to provide sufficient background to provide incisive insights, consistent with qualitative research where information rich cases are pursued for in-depth examination (Patton, 2015).

Data Collection Procedures

Data gathering was integrated within the course (Environmental Science) taken by the preservice teachers under the program, BSEd Mathematics. Throughout the semester, students were introduced to various issues surrounding sustainability, environmental concerns and climate change in line with the Sustainable Development Goals (SDGs) of the United Nations, especially SDG 4 (Quality Education) and SDG 13 (Climate Action).

As a culminating product, the students collectively developed innovative AI-based mathematics lesson exemplars with the inclusion of environmental content knowledge. These exemplars showcased how mathematical topics (e.g., operations, data analysis, modeling with algebra) could be embedded in real-world environmental concerns (e.g., dealing with waste, shifts in climate, loss of biodiversity). Participants were required to utilize artificial intelligence tools (e.g., ChatGPT, Canva or other digital platforms) to support the planning, content production and pedagogical decision-making.

Moreover, this study integrated AI utilization across three stages of lesson design, namely ideation, drafting, and refinement, The PSTs used a generative AI platform (ChatGPT), AI-assisted graphic layout tool (Canva), and AI-enhanced quiz applications (Kahoot and Quizizz). The use of AI influenced planning by generating initial content drafts based on the prompts given by the PSTs for their lesson exemplars, sample problem contexts, and suggested differentiation strategies. However, all content was verified and modified to ensure accuracy, curriculum alignment, and cultural appropriateness, where AI served as a scaffold, rather than a sole developer of the curriculum.

Substantive engagement was assessed using four rubric indicators: (a) alignment to learning competencies, (b) contextual adaptation, (c) verification of mathematical accuracy, and (d) ethical considerations such as bias checking and citation. Monitoring scheme for AI utilization includes prompt logs, screenshots, and annotations that identified which sections of the exemplar were AI-assisted. This enabled transparency and differentiation

between teacher-authored and AI-generated material.

In addition to submitting their lesson exemplars, the student groups each wrote a reflective, guided journal in which they described how they felt about developing the lesson, the role they believe AI played in that effort, and the challenges and ideas they encountered in incorporating environmental stewardship into teaching mathematics. These two sources, the lesson exemplars and the reflection journals, comprised the main data for analysis. Hence, AI use was a required component of the culminating output and included in rubric evaluation under accuracy, contextual relevance, and ethical use.

This dual emphasis on product (i.e., the lesson plan) and process (i.e., reflection) created opportunity to explore in greater depth the ways in which preservice mathematics teachers represent the synthesis of technology, content, and values in their design of instruction. Generally, AI influenced lesson exemplars at three points: generating initial drafts, recommending visual/multimedia elements, and refining content phrasing. Participants consistently revised AI outputs, reinforcing AI as a partner tool that amplifies teacher agency rather than supplants it.

Data Analysis

Using content analysis and thematic analysis, the study explored the lesson exemplars and group reflection journals. Technology and pedagogical strategies, including integration of environmental themes, were determined using content analysis of the exemplars. Thematic analysis (Braun & Clarke, 2006) on reflection journals was used to examine preservice teachers' reflections on use of AI tools, ethical issues, and perceived challenges and opportunities. This dual approach made it possible to represent a fuller picture of both teaching practices and reflective activities.

The reflective narratives and documentation produced by the participants were analyzed using a thematic analysis approach. The process began with a repeated reading of the responses to gain familiarity with the data and to note initial impressions. Codes were generated based on recurring ideas, expressions, and concerns identified across the reflections. These codes were then grouped into broader categories that represented shared patterns in the participants' experiences.

Throughout the process, the researchers discussed the developing categories and compared perspectives to ensure that the themes reflected the data in a fair and reasonable manner. Differences in interpretation were addressed through conversation and consensus rather than a highly formalized statistical procedure, as the intention was to arrive at a grounded understanding of the participants' collective insights. Themes were finalized once similar ideas consistently emerged and no new patterns were observed in the remaining reflections.

This method provided a practical and flexible way to analyze the data, allowing the themes to develop naturally from the participants' own words and experiences while acknowledging the interpretive role of the researchers in shaping the final thematic structure.

Results

Technological and Pedagogical Strategies and Content Connections in AI-Enhanced Environmental Math Lessons

Preservice mathematics teachers demonstrated a sophisticated integration of environmental stewardship by employing student-centered pedagogies such as problem-based learning and collaborative tasks (see Table 1). Rather than treating environmental themes superficially, mathematical concepts served as analytical tools for exploring critical issues; for instance, students used set theory to classify waste, modeled biodiversity loss with algebraic equations, and analyzed climate trends using statistical graphs. These strategies fostered critical thinking by rooting abstract mathematical operations, like unit conversions and percentage calculations, in tangible sustainability contexts such as pollution tracking and energy conservation.

Table 1. AI-Enhanced Environmental Mathematics Lessons

Group	Grade Level	Math Concept	Pedagogical Strategies Used	Technologies Used	Environmental Concept	How Environmental Concept is Integrated
1	7	Conversion of Units (Metric & English Systems)	Real-world contextualization, collaborative group work, guided examples, problem-solving, warm-up activities, use of visual aids, performance tasks	Google Slides, PowerPoint, Quizizz, Kahoot, Wordwall, Google Forms, Liveworksheets, Jamboard, Canva, Prezi	Carbon emission calculations, water usage, climate change	Used real-world problems involving measurements in pollution, rainfall, and carbon emissions to contextualize conversions.
2	7	Sets, Subsets, Union & Intersection, Venn Diagrams	Group discussions, brainstorming, real-life contextualization, drawing and labeling sets, creating Venn diagrams, individual and group exercises	None explicitly stated (basic classroom tools assumed)	Sorting and classifying for segregation (waste/environmental org)	Applied concept of sets in classifying environmental items (e.g., reusable vs non-reusable) and illustrated segregation using Venn diagrams.
3	7	Percentage Increase and Decrease	Think-Pair-Share, problem-based learning, scenario analysis, interactive games, task cards, storytelling, guided practice, performance tasks	Wordwall, Canva, YouTube (tutorials), Activity Sheets, Printed modules	Carbon emissions tracking, pollution reduction, sustainability	Used percentage change to evaluate impacts of sustainable practices such as reducing carbon use, plastic, energy, and transport.
4	7	Operations on Integers	Real-life problem solving, contextualized examples, interactive questioning, guided practice, generalization, Kahoot-based	Kahoot!, PAGASA data sources	Heat index fluctuations, climate change, urban heat island effect in Bulacan	Local heat index data was used in math problems; students applied integer operations to solve real-world temperature-based scenarios.

Group	Grade Level	Math Concept	Pedagogical Strategies Used	Technologies Used	Environmental Concept	How Environmental Concept is Integrated
			formative assessment			
5	7	Statistical Data Analysis and Graphs	Interactive polls, group collaboration, bar graph analysis, real-life data interpretation, peer feedback, environmental integration	Canva, Mentimeter, PAGASA website	Typhoon impact (rainfall, wind, damage), extreme weather events, sustainable development	Students analyzed real typhoon data and linked it to climate effects; they discussed environmental impacts and suggested preparedness actions based on graphs.
6	7	Algebraic Expressions	Word wall vocabulary hunt, worked examples from real life, mini-activity translations, contextualized biodiversity problems, matching-type assessment	YouTube videos, DepEd Tambayan modules	Population dynamics, biodiversity loss, deforestation, species growth and decline modeling	Students translated real-world biodiversity scenarios (e.g., population growth/decline, deforestation) into algebraic expressions, linking math to ecology
7	7	Addition and Subtraction of Rational Numbers	Interactive discussion, real-life word problems, card sorting activity, worked examples, CHIPS method, problem-solving and reflection	Pear Deck app, YouTube video: Nature is Speaking by Lea Salonga, DepEd Tambayan math module	Environmental awareness, forest degradation, deforestation	Environmental scenarios (e.g., forest cover loss, tree planting) were embedded in problems involving rational numbers; students reflected on eco-actions.
8	10	Experimental and Theoretical Probability	Sorting game, real-life scenarios, group experiments, visual presentations, data analysis, group presentations and infographic creation	YouTube videos on waste management, Canva, Google Drawings, DepEd Tambayan module	Waste management, trash segregation, recycling awareness	Students conducted probability-based waste audits, used data to design solutions, and applied math skills in sustainability-oriented project-based tasks.

This pedagogical approach was reinforced by the strategic use of intelligent digital platforms and culturally responsive content. Tools like Canva, Kahoot, and YouTube facilitated visualization and interactivity, while the inclusion of local data, such as Bulacan's heat index and PAGASA typhoon records, ensured the lessons were relevant to the students' immediate environment. By aligning abstract math with local cultural contexts and leveraging multimedia for emotional engagement, the exemplars moved beyond decorative examples to achieve a value-centered, deeply contextualized learning experience.

Across groups, three cross-cutting pedagogical patterns emerged: (a) AI-supported contextualization enabled embedding sustainability issues in mathematically authentic scenarios; (b) the use of AI-powered visual and interactive platforms promoted inquiry and student engagement; and (c) sustainability themes moved mathematical learning beyond computation toward interpretation, argumentation, and reflection. These patterns

indicate a consistent pedagogical orientation toward contextualized and value-based mathematics instruction.

Reflections on the Use of AI-Enhanced Lesson Exemplars for Promoting Environmental Stewardship

On analyzing the reflection journals, the researchers identified four interwoven themes that illuminate how the preservice mathematics teachers were engaging with AI-enriched lesson exemplars intended to promote the infusion of environmental stewardship into mathematics lessons (see Table 2). These themes represent how the students perceive the functionality of AI, the ways in which they accommodate its outputs to their needs, their strategies around the use of sustainability concepts and the ethical considerations on the use of AI in the classroom.

Table 2. Use of AI-Enhanced Lesson Exemplars for Promoting Environmental Stewardship

Codes	Categories	Themes
AI as tool for structuring content, saving time	Functionality of AI	AI as a Practical and Supportive Teaching Tool
Localized examples, age-appropriate rewording, alignment with curriculum	Adaptation and localization	Reflection on Contextualizing AI-Generated Content
Use of environmental examples, sustainability themes	Integration strategies	Intentional Environmental Integration in Math Lessons
Critical vetting, ethical boundaries, balancing roles	Ethical awareness	Reflective and Responsible Use of AI

AI as a Practical and Supportive Teaching Tool

There was wide recognition among preservice teachers of the benefits of AI for organizing lesson content, brainstorming and planning efficiency. AI resources such as ChatGPT were commonly found useful in mapping curriculum standards to learning objectives and packaging the flow of instructional pieces. As one group reflected, "*AI helped streamline the alignment of curriculum standards, learning competencies, and interdisciplinary integration…*" (Group 6). Another shared, "*Using AI... helps the teacher a lot in terms of saving time.*" (Group 1). These accounts describe the function of AI as a teaching assistant that helps in the development in the initial lesson construction.

Reflection on Contextualizing AI-Generated Content

Informants also validated AI's utility and attempted to minimize their cultural inappropriateness, leading to a thoughtful adaptation. Preservice teachers stressed the importance of tailoring the examples so they are age-appropriate and locally relevant. For instance, Group 2 noted, "*Examples were revised to reflect local items and familiar daily scenarios…*", while Group 7 stated, "*We critically modified these examples... not tied to politics.*" These statements point to preservice teachers' emergent ability to exercise discretion and pedagogic judgement to make certain that AI-enhanced resources are appropriate to the lived experiences and the professional standards of their students.

Intentional Environmental Integration in Math Lessons

The present informants appeared demonstrated deliberate efforts to integrate facets of environmental issues with mathematics in a meaningful way. They referred to mathematical topics, such as set theory, rational numbers, and algebra, and linked them to the issues of sustainability. One group reflected, *"Linking set operations to sorting recyclable and non-recyclable materials allowed students to see the practical relevance of mathematics to environmental advocacy."* (Group 2). Another shared, *"We utilized an AI tool to provide examples involving Filipino mothers who are at the same time, environmental advocates."* (Group 7). These reflections signal a pedagogy that conjoins knowledge, environmental awareness and place.

Reflective and Responsible Use of AI

A common thread through the journals was the informants' ethical mindfulness in AI. They stressed the importance of verifying their information, sustaining their environmental messages and not relying too heavily on AI-produced products. Group 8 emphasized, *"We are ethical in our use of AI... applying our critical judgement."*, while Group 7 reflected, *"We verified that each environmental integration actually aligned with the individual's advocacy."* These comments demonstrate that members did not view AI adoption as a purely technical process, but rather as a professional and ethical duty. These themes demonstrate ways in which preservice teachers approached AI as a pedagogical tool to think critically about it and reflect on AI system as a platform for sustainability. Their responses also demonstrate a promising ability to combine technology, values and subject matter in ethically grounded, contextually appropriate and instructionally effective ways.

Challenges and Opportunities in Utilizing AI Tools for Environmental Education

Thematic analysis of reflection journals identified four themes that characterize the opportunities and challenges that preservice mathematics teachers faced learning to use AI tools in preparing lessons for environmental education (see Table 3). These themes demonstrate how AI is a dual figure that both serves the pedagogical innovation and demands critical and ethical attention.

Table 3. Perceived Challenges and Opportunities in Utilizing AI Tools for Environmental Education

Codes	Categories	Themes
Time-saving, content flow, activity suggestions	AI as assistant	Efficiency and Planning Support from AI
Environmental examples, video suggestions, real-life contexts	Enriching content	Expanding Environmental Education Resources
Need for localization, simplification, avoiding bias	Adapting AI output	Challenges in Contextualization and Appropriateness
Critical use, ethical vetting, prompt refinement	Responsible practice	Developing Ethical and Reflective AI Use

Efficiency and Planning Support from AI

In the first theme, the role of AI as a useful auxiliary when preparing lessons, creating content and saving time, as perceived by the preservice mathematics teachers, is evident. Several respondents indicated that AI-induced tools supported lesson design by producing first drafts and conforming instructional elements. As Group 6 shared, *"AI played a valuable role as a planning, content generation, and idea-refinement tool,"* while Group 1 remarked, *"Using AI really helps the teacher a lot in terms of saving time."* These accounts really highlight the practicality of AI in minimizing the time taken to prepare lessons.

Expanding Environmental Education Resources

The second theme describes how AI facilitated the expansion of environmental education resources that diversified interdisciplinary information in lesson scenarios with environmental samples and multiple media. Informants added that AI assisted in pinpointing where in real-life settings sustainability would best be integrated. Group 7 stated, *"We selected the 'Nature Is Speaking' series... aligned with the environmental awareness component,"* while Group 2 explained, *"Linking set operations to everyday sorting tasks... allowed for interdisciplinary connections."* These reflections show how AI played a role in connecting mathematics and environmental education in unique ways.

Challenges in Contextualization and Appropriateness

The third theme is about requiring a critical review of AI-generated content in terms of cultural and curricular fit. Outputs were often edited by teachers to be locally relevant, age-appropriate and pedagogically accurate. For example, Group 2 mentioned, *"Examples were revised to reflect local items... rather than generalized or Western-centric ones,"* while Group 7 adjusted the mathematical content by stating, *"We changed [examples] into simple fractions to maintain consistency."* These responses reveal the limitations of AI to supply fully context-appropriate content and demonstrate human-like judgment.

Developing Ethical and Reflective AI Use

The last theme emphasizes how participants consider their ethical duty in using AI tools. Preservice teachers highlighted the need to verify AI-generated content for accuracy and to adapt such content to instructional goals and values, and to see AI as a support instead of replacing professional judgment. Group 7 shared, *"We verified that each environmental integration actually aligned with the individual's advocacy,"* and Group 8 added, *"We are ethical in our use of AI... and apply our critical judgment."* These are expressions of an emerging ethic and sense of mindful responsibility for learning design.

These themes point to a dual role of AI for the preservice teacher, which allows for strong educative benefits in efficiency and rich access to content while requiring an ethical reflection about teaching, a context-sensitive implementation and a critical oversight on the use of AI. The experience promoted a balanced understanding of

AI as a powerful resource and an empowering innovation in teacher education.

Discussion

This study investigated how preservice mathematics teachers designed and reflected on AI-enhanced lesson exemplars with environmental themes. The results provide a clear image of the developing pedagogical approaches of preservice teachers at the confluence of mathematics education, environmental stewardship and emerging technologies. Four key discussions arise from research questions and thematic analysis.

Fostering Interdisciplinary Connections through AI-Enhanced Lessons

The lesson exemplars showed how mathematical concepts, like unit conversions, algebraic expressions, and probability, could be grounded in a context related to critical environmental issues (i.e., carbon emissions, biodiversity loss, and climate change). These cross-curricular connections are consistent with the increasing mandate for sustainability-based STEM learning to link abstract concepts with real world implications (Karjanto, 2023; Solares-Rojas et al., 2022). In particular, the choices of the preservice teachers to employ strategies when using data from PAGASA, when using local environmental advocates as a scenario, and when using topics of ecology seem to show increasing consciousness of their part in facilitating eco-centric mathematics instruction.

Furthermore, the inclusion of AI-based resources like Canva, Kahoot, and YouTube in the curriculum illustrates that digital resources can be used not only for efficiency, but also to create a more engaging classroom for students and promote consideration of the environment. These findings support our assertion that given appropriate scaffolding, future teachers can arrange technically rich and socially responsible lesson planning experiences, which builds upon prior research that promotes such use of AI and digital tools for contextualized science and mathematics learning (Zawacki-Richter et al., 2019; Holmes et al., 2021).

In the current paper, AI tools have been perceived by preservice teachers to effectively personalize learning experiences, in congruence with the study of Prestoza and Banatao (2024). Furthermore, with the AI tools, they could improve creative ways in teaching learning practice, hence empowering creative education, which is in the same line with the outcome of a study of Hatmanto et. al. (2024). In addition, research shows that AI can account for a high amount of variability in individual learning outcomes, suggesting AI can be effective in diverse contexts of learning. (Agbong-Coates, 2024). Nevertheless, effective implementation is dependent on thoughtful planning, ongoing professional development for teachers, and sufficient technological infrastructure to address problems, including disparities, access, and the changing role of teachers (Maulida et al., 2024). In general, AI-enhanced mathematics classes can serve to bridge the gaps between subjects, equipping students with the mathematics skills they need for a variety of academic and professional challenges.

AI as a Cognitive and Pedagogical Partner

Teachers in this paper considered AI as a functional planning assistant to generate activity ideas, transform content

to suitable level and connect different activities in lessons. This is consistent with literature that re-conceptualizes AI tools as a "mind-extension" mechanism to increase human instructional design capability (Luckin et al., 2016). The preservice teachers did not take AI tools as final authorities, but they perceived them as generative partners that complemented human judgment as part of critical AI literacy framework (Ng et al., 2021).

Teachers' reflections indicate that they shifted from passive consumption of AI-driven content to active molding for instructional use. This matters, in initial teacher education, where AI can either contribute to dependency or provoke critical pedagogical agency (Perrotta et al., 2020). Strategic use of AI-recommended materials to accommodate culturally, age-situational, and curricular appropriateness exemplify a good mix of automation and professional autonomy. Yet, the successful integration of AI in education requires a solid technical infrastructure, sustained teacher training, and a set of ethical standards to tackle issues on data privacy and the perhaps decrease of criticality (Estrellado & Miranda, 2023; Giray et al., 2024). Moreover, while instructors view the remarkable promise of AI to simplify administrative tasks, increase research productivity, and save them time on paperwork, they are also concerned about cheating and data falsification, and call for responsible policies (Giray et al., 2024). In general, the future of AI as a cognitive partner in education is hopeful, but it needs a careful attention to the prior and thoughtful relational frameworks in place to accomplish the most with it (Jose et al., 2022).

Ethical Awareness and Critical Engagement with AI

Although AI was valued for its efficiency and ability to generate content, preservice teachers were being cautious about the outputs that AI produced for them. Many said that they had to modify politically sensitive, Western-centric or highly abstract examples to local realities. These reflections emphasize the need to develop an ethic of future educators to use generative technologies (Tang, 2024; Valerio, 2024). The ethical vetting of AI content, as represented by the respondents, complements developing best practices for teacher education highlighting the importance of transparency, accuracy, and context-sensitive implementation of AI tools (Holmes et al., 2021).

This cautious but imaginative engagement with the technologies is important. It is an example of how preservice teachers could develop their AI-TPACK (Technological Pedagogical Content Knowledge) sensibilities that are responsive to the technical affordances and ethical responsibility (Chiu & Chai, 2020). It also reinforces the notion of teaching ethical AI integration as a pedagogical competence and a reflective practice. This is also congruent with the overarching recommendations that underscore the urgency of having comprehensive ethical frameworks and legal safeguards to inform AI governance in the Philippines (Arcilla et al., 2023) and of improving AI literacy and developing policies that center on ethical considerations in AI deployment in various sectors (Miranda et al., 2025).

Challenges in Contextualization and Sustainability Integration

Despite these affordances of AI, the preservice teachers reported that they struggled to contextualize generic outputs. This is consistent with the known limitations of large language models in covering local and culturally specific content (Bender et al., 2021). Yet, these struggles were helpful, as they led to more explicit pedagogical

consideration and continuous lesson improvement. Preservice teachers made decisions on how to simplify sophisticated content, personalize stories, and relate a lesson to the typical events in the experiences of learners including skills crucial to adaptive expertise in teaching (Hatano & Inagaki, 1986). Furthermore, with the diverse social and cultural landscape in the Philippines, culturally responsive mathematics education is vital, but educators find it challenging to create curriculum that is relevant to culture, particularly Indigenous students (Alangui, 2017).

Furthermore, the attempt to deliberately integrate the theme of sustainability throughout a variety of mathematical content areas reflects a significant level of commitment to education for sustainability development (ESD). This infusion is also congruent with the Sustainable Development Goals and with the recommendation to mainstream environmental ethics across the curriculum (UNESCO, 2017). Therefore, this study confirms the importance of a model that integrates sustainability in mathematics education, although initial teacher training does not currently offer the required emphasis on environmental and social problems. Successful integration of sustainability involves reflection and the environmental aspects that are not often considered in traditional curricula (Alsina & Calabuig, 2019).

The findings reflect TPACK intersections as participants negotiated technological affordances with pedagogical constraints and content accuracy. SRL processes surfaced in their monitoring and modification of AI-generated content. Social Constructivism framed AI as a mediating tool supporting shared meaning-making during collaborative planning.

In addition, results indicate a need for teacher education programs to provide structured experiences for exploring AI, engaging in reflective process, and creating interdisciplinary curricula. Professional growth opportunities should also highlight ethical and contextual dimensions, so that future educators can interrogate AI with care and remain situated in the learning needs of children and the social responsibilities of educators. Likewise, rather than aligning uniformly with existing research, this study exposes a gap: AI lacks cultural specificity and requires teacher adaptation, an issue not addressed in global scholarship. The findings suggest that AI literacy is not solely technical competence but cultural-pedagogical discernment. The integration of AI not only influenced lesson content but reshaped pedagogical practice, supporting more inquiry-oriented, data-informed, and socially relevant mathematics instruction. This implies the need for programs that develop AI literacy alongside reflective instructional judgment.

Conclusion

This study explored the way that preservice mathematics teachers design and reflect on AI-enhanced lesson exemplars that integrate environmental concepts in the realm of secondary mathematics education. Analyzing the group reflection journals through a document and thematic analysis process, the research discovered how the preservice teachers navigated the opportunities and challenges of engaging with AI tools in interdisciplinary teaching situations. Their reflections disclosed a pedagogical development which included the practices of contextually embedded lesson planning, intentional environmental integration, and ethical AI-use applications. The results highlight the innovative power of AI in the role of pedagogical partner and not as a replacement for

teacher agency. AI tools were used as idea-generators, content organizers, and as environmental contextualizing tools, as well as encouraging teachers to critically reflect on outputs and modify materials for learners and local situations. The preservice teachers exhibited growing AI-TPACK mindset, optimized with technological fluency, pedagogical reasoning, content knowledge, and ethical reflection.

Recommendations

According to the results of this study, several suggestions are presented to enrich the preservice teacher education in the era of artificial intelligence and the sustainability challenges. First, it is essential to ensure that teacher education institutions incorporate AI literacy and critical pedagogy as part of their curriculum. Preservice teachers need to encounter not just the mechanics of AI tools, but also the related practices of prompt engineering, ethical vetting, bias identification, and cultural adaptation. This will enable towards advancement of a generation of critically literate practitioners who will not use AI for the sake of efficiency, but for pedagogical innovation and fairness.

Second, there should be a design of preservice coursework that encourage interdisciplinary and contextual curricula development. There is a need to train the preservice teachers to do more than just deliver mathematics, but to instead provide experiences where mathematics speaks to relevant societal and environmental challenges. Collaborative projects and problem-based learning, those which involve use of local data, evidence sustainability concepts, and situations that have authentic uses, may support this integration.

Third, reflective practice must be developed as a main component of teacher education. Organized reflection, via activities like group journals, dialogic feedback, and thematic analysis exercises, can support a stronger metacognitive awareness and critical reflection about technology use. These strategies help preservice teachers go deeper than the superficial adoption of AI and develop a sophisticated understanding of how, why, and when to employ AI in educational contexts. A limitation of this study lies in the use of group reflections, which may mask dissenting viewpoints and present negotiated consensus instead of individual cognitive shifts. Future research should incorporate individual interviews or think-aloud protocols. The findings support the need for (a) dedicated AI literacy coursework, (b) development of localized exemplar banks to supplement generic AI outputs, and (c) embedding ethical AI vetting as a core reflective practice.

Finally, institutions should invest in the creation and distribution of localized content that accompanies AI-produced resources. Repositories of context and culture-specific teaching resources are emerging as they are required to realize this bridge between generic AI outputs and meaningful situations in classroom teaching. Such efforts will help prevent the use of AI in education from being limiting into a learner-centered, contextually appropriate, and value-laden community.

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