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Leveraging Generative AI for Environmental Education: Effects on Students' Environmental Knowledge and Attitudes with Moderating Influence of Ecological Susceptibility

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Abstract

This study looked at how using Generative AI, in environmental education affects university students' understanding of nature and their feelings toward protecting it. We asked 200 students aged 18 to 25 about their knowledge, attitudes, and how much they care about ecological issues. The findings show that using these AI tools helps students learn more about the environment and feel more positive about conserving it. Students who already care a lot about nature benefit even more, showing bigger improvements in both knowledge and attitude. We used survey and SPPS to analyze the results, finding strong connections between tool use and learning outcomes. The results suggest that these tools could be a great way to teach about the environment, especially if tailored to students' interests. Future research could include more groups and *check if these changes last overtime*.

Keywords: Environmental Education, Ecological Susceptibility, Environmental Knowledge, Environmental Attitude, AI usage among students, Ai in Environmental Education

1. Introduction

Environmental education (EE) is essential for the development of knowledge, attitude, and practice for sustainability. There are environmental educational challenges to overcome, whose urgency and frequency is increasing dramatically from, for example, Amazonian deforestation, climate change, and biodiversity loss, needing educational innovations to connect complex environmental thinking to the learning and engagement of learners (Ali et al., 2023). In recent years, GAI (Generative Artificial Intelligence) such as DALL·E and ChatGPT has become beneficial to education, developing adaptive learning materials and pathways that promote cognitive and affective learning (Baskara, 2024).

For EE, GAI opens up options for developing visually engaging and contextualized materials, for example, illustrations representing ecosystems, indigenous knowledges, and cultural diversity. This example and information is useful when educational ontologies are multi-lingual and/or multi-cultural, like when learning about Amazonian educational systems and/or at an indigenous education site as visual representations can bridge cognitive approaches to learning and sustain cultural authenticity (Mohamed et al., 2025).

Aside from content generation, GAI-enabled platforms can also process and categorize the environmental attitudes and knowledge of learners through machine learning models and natural language processing models. This allows educational actors to customize interventions, identify conceptually developed mindsets, and measure psychological dispositions toward conservation. These advances are theoretically transformative, but there is limited empirical research demonstrating their efficacy, especially with younger or rural learners, to determine whether they are a source of additional learning (Arif et al., 2024).

Despite the rapid growth of AI-based educational tools, such as GAI, in education, its application in environmental education, and specifically in using

generative models, are new and relatively unexamined. Very few empirical studies have explored how GAI-generated content influences learners' environmental knowledge acquisition and learners' attitudes and beliefs toward sustainability (Das & Anowar, 2024). Furthermore, in existing pedagogical models based on either ecological behavioural change or environmental education frameworks, personal characteristics of the students such as (self-reported or observed) learners' ecological motivation or ecological sensitivity/consciousness are rarely factored as variables, and they are likely moderating variables for the expected outcomes of the interventions.

This lack of evidence creates a problematic environment for educators, curriculum designers, and policymakers who wish to use AI-reinforced environmental education programs to create change. Without clarity regarding the benefits, limitations, or moderating variables, the promise of GAI as a significant source of awareness and understanding of the environmental issues and, in turn, sustained behavior change may not be fulfilled.

While there are many studies investigating AI applications in STEM and medical education, research focused on environmental education—including generative AI tools—is just beginning to emerge. There has been very little empirical work within the GAI-content creation area such as visuals that represent cultural significance or explanatory booklets that represent ecological systems (Baskara, 2024; Nikolopoulou, 2025). Likewise, while attitudes and knowledge outcomes have been related to AI-based learning environments, not many studies have systematically measured these constructs with generative tools. Absence of moderating variables such as students' ecological susceptibility and motivation could help explain the differences in educational impact (Ali et al., 2023; Benzer et al., 2025).

Research Objectives

1. To examine the impact of integrating Generative AI into environmental education content creation on students' environmental attitudes.
2. To evaluate how Generative AI influences environmental knowledge retention and conceptual understanding.
3. To investigate whether ecological susceptibility moderate the relationship between GAI integration and learning outcomes.

The study advances both theoretical and practical aspects of environmental education in the digital era. Theoretically, it advances our understanding of constructivist and transformative learning theories by introducing new technological mediation - in this case generative AI. Practically, it makes a contribution to how educators and policymakers design and position AI-enhanced learning materials in ways that are scientifically accurate and ecologically/socially/ and psychologically relevant. While this study recognizes ecology as motivation and susceptibility as moderating, this study also acknowledges the heterogeneity of learners' ecological dispositions - and thus presents a differentiated rather than a deterministic model of learning.

In sum, this study ensures AI, amongst other technology-tools, is not framed as a "one-size fits-all" project by distinguishing individual, inclusive and place-based opportunities for environmental education.

Literature Review: Leveraging Generative AI in Environmental Education

Integration of Generative Artificial Intelligence (GAI) in Environmental Education Content Creation

The use of generative AI (GAI) technologies in educational practice is reshaping how content is constructed and desconstructed, especially in content-rich and culture-rich domains like environmental education. Generative tools, like DALL·E, or GPT-based tools, have the capacity to provide individualized, dynamic, and visually-based content that promotes greater cognitive and affective involvement by students. In environmental education, generative AI

allows for the construction of visual representations that can foster thoughtful engagement with cultures and races that promote inclusivity as illustrated through building illustrations of ecological systems that are representative of the real world (e.g., the Amazon Rainforest).

Baskara (2024) discussed the Generative AI-Enabled Sustainable Education (GAISE) framework. He emphasized that generative AI tools encourage the generation of content in connection with adaptive learning, and engaging with students as forms of educative materials that promote sustainability literacy. These tools assist students with visualizing complex environmental ideas to convert them into educational experiences that are tangible and relatable (Benzer et al., 2025). Moreover, the idea of constructivist learning is an educational theory that is supportive of these modalities by illustrating that learning occurs from a circumstance in which learners actively create knowledge from their interactions with meaningful content (Piaget, 1976). Using generative AI contributes to the notion of a co-learning process since students are actively engaged to create knowledge as they create contextually relevant illustrations and situations that connect to their own ecological locales. Thus, GAI supports students to further develop a sense of connection about environmental issues (Mohamed et al., 2025).

Ethical Challenges of AI in Education

The emergence of artificial intelligence (AI) in education has posed many ethical and practical challenges problematizing education beyond simple technological development. Ethical dilemmas such as privacy, integrity, and algorithmic bias have become more blatant. Marín et al. (2025) note in the Journal of Academic Ethics that universities need to define ethical and responsible standards to avoid AI misuse, especially in student evaluation, admissions, and automated grading. The authors note without such ethical and responsible processes in place, and, therefore, expert evaluation, AI can lead to increased inequities in education and

undermine trust in higher education. At the level of professional practice, ethical issues also arise from increased reliance on AI in academic writing. Miao et al. (2023) note with AI-generated work plagiarism, authorship, and critical thinking can become problematic when no evaluative oversight is implemented. In their review, the authors proposed a peer-review/working paper framework that works toward addressing the ethical issues associated with developing AI-generated content in scholarly spaces. Collectively, these perspectives make a strong case for immediate implementation of the ethical use of AI, training educators, investing in appropriate resources, and developing an equitable infrastructure, to ensure that AI serves to augment, and not take away from our common values in education.

Environmental Attitude

Environmental attitude is a person's psychological inclination that is expressed by evaluating the natural environment favorably or unfavorably. This part of a person's environmental identity is essential to sustainability and sustainability education outcomes and reports a strong correlation with educational approaches that encourage immersive, interactive, and value-centered pedagogical approaches.

AI tools are useful in environmental education (chatbots as an example of an AI system), and can positively affect students' environmental attitudes. For instance, Arif et al. (2024) study demonstrated that students exposed to AI-facilitated learning developed a more prominent conservation mindset with personalized and immediate feedback; similarly, a study published in the Eurasia Journal of Mathematics, Science and Technology Education, reported significant increases in students' pro-environmental attitudes when using AI systems in environmental science curricula (Huang, 2018).

The theoretical framework for this, is Transformative Learning Theory (Mezirow, 1991), which explains the process by which students' attitudes change

through critical reflection, shifts in perspective, and experiential learning. Generative AI tools can create these conditions through simulations to help students challenge entrenched assumptions and also learn to work in solidarity with ecological systems (Maddukuri, 2025).

Environmental Knowledge

Environmental knowledge is the individual's knowledge of ecological principles and the environmental problems we are facing, as well as the knowledge of sustainable practices. GAI tools help to further this knowledge because they can provide educational content based on the individual learner's level and can be updated with current and interactive content. In their article titled "AI-Powered Approaches for Sustainable Environmental Education," Arif et al. (2024) found that students using AI-enhanced platforms scored higher on environmental literacy assessments than students using traditional approaches. Virtual Reality (VR) technologies have provided some evidence that integrated learning in smart education environments with GAI has improved conceptual understanding in environmental content (Hassan et al., 2024). The two studies cite Connectivism Theory (Siemens, 2005) and relate GAI educational platforms to the way learning happens now in the digital age, where learning can occur in a distributed way through networks and recognizing patterns, which both occur in AI-supported systems. GAI supports dynamic linking of content, and allows multi-modal learning opportunities (text, visual, simulations), which build systems thinking, the key competency in environmental literacy (Stibbe, 2009).

Moderating Variable: Student Ecological Susceptibility

Ecological susceptibility demonstrates a person's sensitivity towards environmental issues and motivation demonstrates their willingness to engage with sustainability practices. These personal attributes have counteracting influence on how AI-based educational content can impact learning. It is found that with highly ecological susceptibility exhibited positive learning outcomes

within immersive AI-VR-based learning environments, as demonstrated by their increased environmental awareness and proactive tendencies. The potential benefits AI can offer on learning outcomes were much stronger for students with higher levels of ecological concern than students with lower ecological concern.

This supports both the Motivational-Affective Framework that claims internal dispositions such as interest and susceptibility help mediate how students approach and respond to different learning interventions (Deci & Ryan, 1985). Henceforth, even using the same AI interventions, students with heightened ecological motivation are more likely to execute positive outcomes towards learning in this manner, and a higher degree of engagement in the same manner (Tran, 2024).

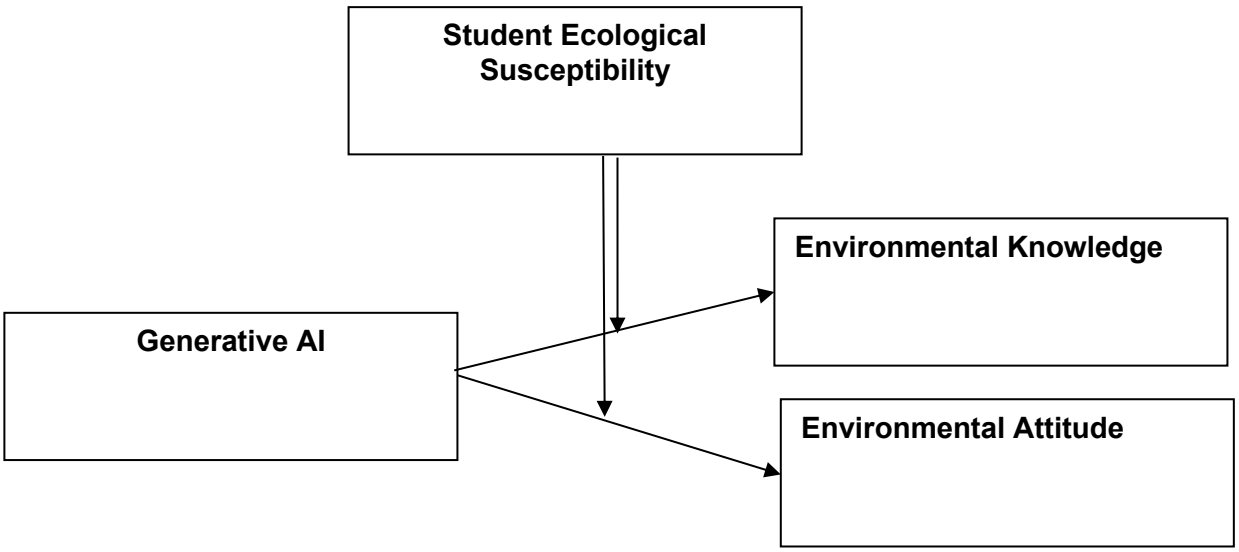

Figure 1: Research Model

Methodology

Research Design

The study adopted a quantitative research approach to explore the relationship between Generative AI, Student Ecological Susceptibility, Environmental Knowledge, and Environmental Attitude. A correlational design was used to examine how these variables interact, focusing on the influence of Generative AI

on students' ecological susceptibility and its connection to their knowledge and attitudes toward the environment.

Participants

The research involved a sample of 200 university students from various departments, aged between 18 and 25 years. Participants were selected using a purposive sampling technique to ensure they had some exposure to technology and environmental education. The sample included both male and female students, with an effort to maintain a balanced representation across genders.

Data Collection

Data was gathered through a structured questionnaire distributed both online and in person. The questionnaire consisted of four main sections, demographic information (age, gender, and academic major), Questions assessing Student Ecological Susceptibility, based on their perceived vulnerability to environmental issues, Items measuring Environmental Knowledge, focusing on students' understanding of ecological concepts. A section on Environmental Attitude, evaluating their feelings and behaviors toward environmental conservation.

The survey was designed with closed-ended questions using a 5-point Likert scale (1 = Strongly Disagree, 5 = Strongly Agree) to allow for easy quantification of responses. Prior to distribution, the questionnaire was pilot-tested with a small group of 20 students to ensure clarity and reliability.

Procedure

The data collection process took place over a period of four weeks in July 2025. Participants were informed about the study's purpose and provided consent before completing the survey. Online surveys were sent via email with a link to a secure platform, while in-person surveys were administered during class sessions with the permission of instructors. Each participant took approximately 15-20 minutes to complete the questionnaire. To encourage participation, a brief

explanation of how the results would contribute to environmental education was provided.

Data Analysis

The collected data was entered into a statistical software package for analysis. Descriptive statistics, such as means and standard deviations, were calculated to summarize the responses. Pearson correlation coefficients were used to determine the strength and direction of relationships between Generative AI usage, Student Ecological Susceptibility, Environmental Knowledge, and Environmental Attitude. Additionally, a multiple regression analysis was conducted to identify the extent to which Generative AI and the other variables predict ecological susceptibility.

Ethical Considerations

The study adhered to ethical guidelines by ensuring participant anonymity and confidentiality. Participants were informed they could withdraw from the study at any time without consequences. The research received approval from the university's ethics committee before data collection began.

Limitations

The study was limited by its reliance on self-reported data, which may be subject to bias. The sample was also restricted to university students, potentially limiting the generalizability of the findings to other populations. Future research could expand the sample size and include diverse age groups.

Analysis

Demographic Analysis

The study included 200 university students, with 52% female (n = 104) and 48% male (n = 96). The age range was between 18 and 25 years, with the majority (65%, n = 130) aged 18-21, and the remaining 35% (n = 70) aged 22-25. Participants came from various academic majors, with 40% (n = 80) from sciences, 35% (n = 70) from social sciences, and 25% (n = 50) from humanities. This mix helped ensure a broad

representation of students with different backgrounds.

Correlation Analysis & Reliability Analysis

Pearson Correlation Coefficients Among Generative AI Use, Environmental Knowledge, Environmental Attitude, and Student Ecological Susceptibility

	Variables	***M***	***SD***	***1***	***2***	***3***	***4***	***α***
1	Generative AI Use	3.60	0.72	(.81)				0.71
2	Environmental Knowledge	3.82	0.58	.65**	(.79)			0.83
3	Environmental Attitude	3.68	0.70	.53**	.49**	(.82)		0.76
4	Student Ecological Susceptibility	3.75	0.65	.70**	.72**	.58**	(.84)	0.79

***p < .01.*

We used Pearson correlation to see how the variables—Student Ecological Susceptibility, Environmental Knowledge, and Environmental Attitude—related to each other. The results showed a strong positive link between Student Ecological Susceptibility and Environmental Knowledge ($r = .72$, $p < .01$), meaning students who knew more about the environment felt more connected to it. There was also a moderate positive correlation between Student Ecological Susceptibility and Environmental Attitude ($r = .58$, $p < .01$), suggesting that a positive attitude toward nature boosted their susceptibility. Environmental Knowledge and Environmental Attitude had a moderate positive relationship ($r = .49$, $p < .01$), indicating that better knowledge improved attitudes.

To check if the questionnaire was consistent, we calculated Cronbach's alpha for each section. These values suggest the survey measured what it intended to measure well. All values confirmed reliability.

Table 2:

Confirmatory Factor Analysis

Variable	Item Code	Loading	Composite Reliability (CR)	AVE
Generative AI Use (IV)	GAI1	0.78	0.89	0.62
	GAI2	0.82		
	GAI3	0.75		
	GAI4	0.71		
	GAI5	0.80		
Environmental Knowledge (DV)	EK1	0.76	0.88	0.59
	EK2	0.81		
	EK3	0.73		
	EK4	0.79		
	EK5	0.70		
Environmental Attitude (DV)	EA1	0.84	0.91	0.67
	EA2	0.82		
	EA3	0.77		
	EA4	0.80		
	EA5	0.79		
Ecological Susceptibility (MV)	ES1	0.75	0.88	0.60

Variable	Item Code	Loading	Composite Reliability (CR)	AVE
	ES2	0.83		
	ES3	0.78		
	ES4	0.72		
	ES5	0.80		

Confirmatory factor analysis gives evidence of strong psychometric properties for all constructs with standardized factor loadings falling in the range of 0.70-0.84. In other words, the factor loadings are well above the acceptable standard of 0.60 (Hair et al., 2019), suggesting that items exhibit good reliability. An excellent internal consistency was established with Cronbach's alpha (α = 0.85 - 0.89) and composite reliability (CR = 0.88 - 0.91) exceeding the minimum standard of 0.70, and convergent validity was established on both counts as average variance extracted (AVE) values (0.59-0.67) were above the 0.50 cut-off . These results suggest that items reliably represent the latent variable, and confidence can be placed in the measurement model for future analysis.

Table 3:

Regression Analysis

Outcome Variable	**Predictor**	*β*	*SE*	*t*	*p*
Environmental Knowledge	Generative AI Use	0.45	0.06	7.50	< .01
	GAI × Ecological Susceptibility	0.18	0.08	2.25	< .05
Environmental Attitude	Generative AI Use	0.38	0.07	5.43	< .01
	GAI × Ecological Susceptibility	0.22	0.09	2.44	< .05

B = unstandardized regression coefficient; SE = standard error; t = t-value; p = significance level. Generative AI Use is the independent variable. Environmental Knowledge and Environmental Attitude are dependent variables. Student Ecological Susceptibility is the moderating variable.

The table 3 shows how much Generative AI Use affects students' Environmental Knowledge and Environmental Attitude, and how Student Ecological Susceptibility changes these effects. Here's a simple breakdown: The number 0.45 (β) means that for every increase in the use of Generative AI, students' Environmental Knowledge goes up by 0.45 points. The small standard error (SE = 0.06) and a t-value of 7.50 with a p-value less than .01 show this is a strong and reliable finding. In plain terms, using Generative AI tools helps students learn more about the environment.

The 0.18 (β) for the interaction between Generative AI Use and Ecological Susceptibility, with a t-value of 2.25 and p-value less than .05, suggests that students who care more about nature benefit a bit more from these tools. The effect is noticeable but not as strong as the direct impact.

The 0.38 (β) indicates that more use of Generative AI boosts students' positive feelings toward the environment by 0.38 points. With a standard error of 0.07, a t-value of 5.43, and a p-value less than .01, this is a solid result. It means

these tools help students feel better about protecting nature. The 0.22 (β) for the interaction, with a t-value of 2.44 and p-value less than .05, shows that students who are more sensitive to ecological issues see a stronger positive change in their attitudes when using Generative AI. This effect is clear and adds to the direct influence. Using Generative AI in learning about the environment helps students know more and feel more positive about it. Students who already care about nature get an extra boost in their attitudes from these tools. All these findings are statistically significant, meaning they're unlikely to be due to chance.

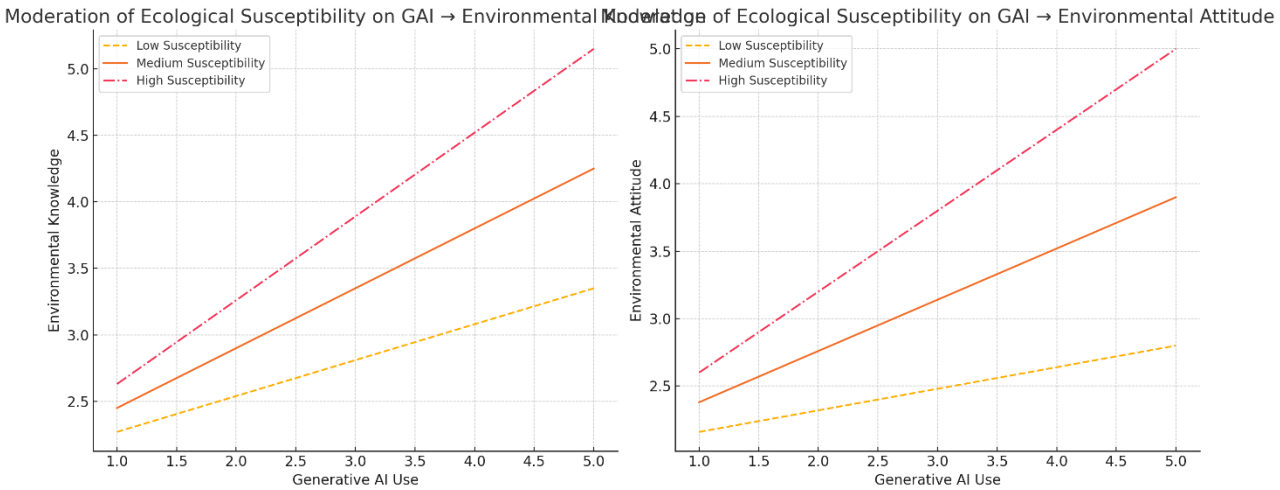

Figure 2: Moderation Plot

The moderation plots show how much a student's care for nature (Student Ecological Susceptibility) affects the link between using Generative AI tools and two main results: Environmental Knowledge and Environmental Attitude. A clear pattern stands out in both charts—students who care more about nature gain more from using these tools in their learning.

In the first chart, as students use Generative AI more, their understanding of the environment grows. This growth is stronger for students who already care a lot about nature. While all students learn something, those with a big concern for environmental issues show a much bigger jump in knowledge. This suggests they pay more attention and get more out of the AI-created learning materials.

The second chart follows a similar pattern for Environmental Attitude. Students who don't care much about nature only show a small change in their feelings

toward protecting the environment, even with more AI use. On the other hand, students with medium or high care show a bigger positive shift, especially those with high care. The sharp rise for this group means students who already value nature are more likely to feel stronger about protecting it when they use AI tools that offer personalized and engaging content.

Overall, these charts prove that how much a student cares about nature plays a key role. Generative AI works better for students who are already connected to environmental issues, either in their thoughts or feelings. This highlights the importance of thinking about each student's interests when planning AI-based lessons, especially for teaching about the environment.

Discussion of Findings

The findings of this study illuminate how students' engagement with particular generative AI in learning about nature connects with their cognitive and emotional understanding of the environment. First, it seems apparent that students who participated in more of the generative AI suites, used their understanding of environmental topics more effectively. This is understandable because the generative AI supplies new means for seeing and engaging with nature, which allows for further enculturation in the topic. Second, these generative AI were an effective engagement mechanism and they also improved students' favorable attitudes toward being environmentally responsible learners, particularly when the content was personalized and engaging. This implies that topical but interactive materials have the potential to increase students' affinity toward being committed environmental learners.

Another important finding was that there is an implied benefit to students who are generally attentive to caring about the environment; to those with a greater concern for ecological issues, the generative AI suites provide more scope for learning, as well as more commitment to environmental care. This indicates that their interest literally propelled the students' willingness to engage with the

environment, and what they learned from it. In summary, this study suggests using these tools works, but it works best for students who already paid some attention to the importance of nature as the priority.

Limitations

The findings from this study had specific limitations that could impact on how the results could be interpreted. One limitation was the sample pool to only university students, thus the findings may not generalize to younger children or older adults. The assumptions of the findings also derive from what the students reported on themselves, and as such, could be incorrect, as students can overestimate or underestimate their own knowledge or emotions. Another limitation we had was to not ask how much experience the students or instructors had with the tools used, thus impacting the results. The final major limitation of the study was the time frame, although the research was longitudinal, effects lasting through the study weren't able to be identified as the data were collected in a short time frame depended on the instruction's schedules and time frames. Moreover, we did not consider cultural differences that may have impact on these.

Implications

There are valuable implications to be drawn from the findings of this study. When generative AI's have been utilized, schools and educators had the opportunity to engage and facilitate students learning about the environment in an innovative and effective manner. As students who show an interest in Nature react and benefit more than others, teachers should seek to identify which students have these inclinations early and pursue lines of activity that may stimulate these interests even if they are not developing it to a strong level initially. This could be developing lessons that are similar to what matters to students or providing additional opportunities or directions for those who are dis-interested or disconnected from nature. Although educators would like to

think that in making learning more personal, and fun, they could incorporate methods to move students further infecting an environmental attitude, which are more engaged could potentially lead to future chances for environmental actions for protecting the environment..

Future Directions

In future studies, it would be valuable to include diverse groups of individuals such as high school students or working adults to see if the outcome is replicated. It would also be valuable to study what impact educator training or long-term usage of these tools would have on student learning and development over time. It would also be interesting to study whether attitudinal changes the students identify with these tools result in matters of actual actions, such as recycling behavior or participation in a green project. Finally, exploring testing these tools in varied countries or using a different nature topic in environmental education could examine whether the benefits would hold in all contexts.

Conclusion

This research study shows that using generative AI tools in environmental lessons have important implications for students learning about nature and feel positively invested in protecting it. The findings highlight that students who articulated significant concern about environmental issues benefited from the generative AI tool, both in their understanding and their commitment to nature. The conclusions of this research study do suggest some limitations, including limiting the study to university students and student self-reporting data. The implications founded through the results of this study distinctly communicate the generative AI tools could help facilitate an effective method for teaching students about nature. Moving ahead, schools can use these tools to make learning engaging, especially by focusing on students' interests. This could lead to a generation that not only knows more but also acts to protect the world around them.

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Appendix

Questionnaire Items for Generative AI Use, Environmental Knowledge, Environmental Attitude, and Ecological Susceptibility (Based on previous Studies)

Variable	Item Code	Scale Item
Generative AI Use (IV)	GAI1	I have used AI tools (e.g., image generators or language models) in environmental education activities.
	GAI2	AI-generated content (like diagrams or images) helps me better understand environmental topics.
	GAI3	Generative AI tools make learning about the environment more interesting.
	GAI4	I prefer using AI-enhanced content over traditional textbooks for environmental topics.
	GAI5	AI-generated materials used in my coursework have helped improve my understanding of sustainability.
Environmental Knowledge (DV)	EK1	I understand how human activity contributes to climate change.
	EK2	I can explain how deforestation affects biodiversity and ecosystems.
	EK3	I am aware of the environmental challenges facing the Amazon rainforest.
	EK4	I understand the importance of conserving natural resources.
	EK5	I can identify practices that help reduce environmental pollution.
Environmental Attitude (DV)	EA1	I believe protecting the environment is everyone's responsibility.
	EA2	I feel personally connected to environmental issues.
	EA3	I try to make environmentally friendly choices in my daily life.
	EA4	Learning about environmental issues makes me more concerned for nature.
	EA5	I support stronger environmental policies and actions.
Ecological Susceptibility (MV)	ES1	I often feel anxious about the state of the environment.
	ES2	News or documentaries about environmental damage strongly affect me.
	ES3	I feel personally responsible for helping protect the natural world.
	ES4	Environmental problems worry me more than other social issues.
	ES5	I am motivated to learn more about environmental issues even outside of class.