CHALLENGES AND OPPORTUNITIES: INTEGRATING AI-CHATBOTS IN ENVIRONMENTAL EDUCATION FROM STUDENTS' AND INSTRUCTORS' PERSPECTIVES

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Abstract: Environmental education faces challenges such as low student engagement, teacher-centered instructional models, and a lack of practical, situated learning. These traditional methods often fail to bridge theoretical knowledge with real-world applications, leading to a superficial understanding of environmental issues and diminished student motivation. As environmental sustainability becomes a global priority, innovative educational approaches are needed to promote environmental literacy effectively. This study explores the potential of AI-chatbots to address these challenges by enhancing learning engagement, creating personalized experiences, and fostering critical thinking and problem-solving skills. Data was collected through face-to-face and email interviews with eight environmental studies students from freshman to senior year and five expert teachers in Environmental Science, Educational Technology and Artificial Intelligence. Thematic and content analyses revealed five major challenges in traditional environmental education: lack of environmental knowledge, teacher-centered instruction, insufficient situated learning, low engagement, and limited teacher-student interaction. AI-chatbots have been identified as promising tools for addressing these issues. However, expert teachers recommend using AI as a supplementary tool to traditional methods, emphasizing the need for a balanced approach to avoid over-reliance and misuse.

Keywords: AI chatbot learning, environmental education, generative AI, environmental sustainability.

INTRODUCTION

Pollution of the natural environment has become a critical problem facing humankind in the 21st century. Data from the World Health Organization (2023) show that around 2.4 billion people are exposed to dangerous levels of household air pollution, and the combined effects of ambient air pollution and household air pollution are associated with 7 million premature deaths annually. 9% of the world's population drinks water from unimproved and hazardous sources, and 90% of effluent in developing nations is discharged untreated directly into water bodies. Behind those cold data is a series of consequences of environmental destruction. As such, people globally began to recognize the need to conduct themselves more responsibly towards nature. Environmental sustainability has become a global concern for governments, organizations, and individuals (Boca & Saraçl, 2019). In response to these widespread concerns, the global community developed the Sustainable Development Goals (SDGs) as a comprehensive plan for achieving sustainability. A key element of the SDGs is the focus on quality education, which aims to increase awareness and understanding of sustainable development (Al-Sharafi et al., 2023). Central to achieving these educational goals is environmental education, which has long been recognized as a critical component in fostering environmental literacy and promoting sustainable behaviors among students (Sarbassova et al., 2021). Traditional environmental education methods, which rely heavily on teacher-centered instruction, aim to provide students with the knowledge and skills necessary to understand and address complex environmental issues. However, the effectiveness of this approach has been discovered to be unsatisfactory (Chen & Zhou, 2019). AAAS (2009) stated that learning outcomes in lecture-only courses are elementary and primarily involve memorizing information. As a result, students often perceive these courses negatively, considering them

insignificant to their everyday lives. Consequently, students may perceive environmental education as abstract and disconnected from their daily lives, resulting in a lack of motivation and engagement (Ardoin & Heimlich, 2021).

In response to these challenges, educators and researchers increasingly explore innovative instructional methods that leverage technology to enhance learning experiences. Recently, one promising approach has been the integration of artificial intelligence (AI) in educational settings, which has the potential to transform traditional pedagogical practices by providing personalized, interactive, and engaging learning environments (Silva & Janes, 2020). AI-chatbots are a new learning instrument in educational technology. They offer tutoring, feedback, and emotional support, which can greatly improve learning (Cao et al., 2023). These chatbots mimic human interactions, allowing them to answer student questions, give immediate feedback, and personalize learning activities (Dimitriadis, 2020). Moreover, the scalability and accessibility of AI-chatbots can overcome logistical barriers associated with traditional methods, making quality education more widely available (Wollny et al., 2021). These features make AI-chatbots particularly well-suited for addressing the limitations of traditional environmental education by promoting active engagement, facilitating continuous interaction, and offering tailored support based on individual learning needs (Iku-Silan et al.,2023).

This study addresses the urgent need for innovative approaches in environmental education by recognizing the transformative roles of AI-chatbots. By identifying specific issues that hinder student engagement and learning, educators can develop targeted solutions to enhance educational effectiveness. Teachers' insights on the opportunities and suggestions for applying AI-chatbots provide essential guidance for seamlessly integrating these tools into classrooms.

This study examines students' obstacles in traditional environmental education and explores some opportunities AI-chatbots bring to support teaching and learning in higher education settings. The goal is to provide actionable insights for integrating AI-chatbots to improve learning outcomes and environmental literacy.

The following research questions guided this research:

1. RQ1: What challenges do students encounter in traditional environmental education?
2. RQ2: What opportunities does the integrating of AI-chatbots in environmental education?
3. RQ3: What suggestions do expert teachers have for the integrating of AI-chatbots in environmental education?

METHODS

Research Design

This study explored students' and teachers' perceptions of challenges in traditional environmental education, opportunities, and suggestions for integrating AI-chatbots into this field. Data collection occurred in two phases. The first phase investigated challenges students face in traditional environmental education. The second phase examined expert teachers' perceptions towards opportunities and suggestions for integrating AI-chatbots. Data were collected through face-to-face semi-structured and email interviews at a local higher education institution. These in-depth interviews provided detailed information on classroom challenges and potential opportunities towards AI-chatbots. Thematic and content analyses were employed to identify patterns and themes, offering insights into classroom challenges and the opportunities AI-chatbots bring to environmental education.

Participants

Purposive sampling is a non-probability method where participants are chosen based on predetermined criteria or objectives (Schreuder et al., 2001). Through purposive sampling, participants were carefully chosen to provide highly relevant and comprehensive information. This method ensured the inclusion of participants with domain knowledge who could offer expert feedback on challenges faced in traditional classrooms and the opportunities and suggestions for integrating AI-chatbots in environmental education. Therefore, participants were recruited based on specified research criteria. The inclusion criteria were as follows:

Table 1.
Selection Criteria for Student and Expert Teacher

Categories	Academic qualifications	Professional experience	Contextual knowledge	Personal preference
Student	Enrollment at a local higher educational institution (HEI)	Major in environmental education (e.g., Environmental Science, Environmental Engineering, Ecology)	Familiarity with educational technology; and knowledge in the field of environmental education	Willingness to participate
Expert Teacher	At least a Master's degree in a relevant field (e.g., Environmental Science, Educational Technology and Computer Science)	Minimum of five years in their respective disciplines	Familiarity with the AI-chatbots, higher education system and its environmental education requirements	Willingness to participate

Based on the selection criteria, the study sample for RQ1 consisted of 8 students (4 females and 4 males) from the departments of Environmental Engineering, Environmental Science, and Ecology at a local university. For RQ2 and RQ3, five expert teachers with 6 to 12 years of work experience were selected, all meeting the inclusion criteria.

Data Collection

Data were collected through face-to-face semi-structured and email interviews to understand students' views on traditional educational challenges and teachers' opinions on opportunities and suggestions to integrate AI-chatbots in environmental education. Each interview lasted about 30 minutes, with recordings transcribed for detailed analysis. Semi-structured interviews were selected for their capacity to explore complex behaviors, opinions, and emotions. They are also selected to gather diverse experiences (Longhurst, 2009). Email interviews are particularly useful for qualitative research when logistical issues make face-to-face or phone interviews impractical (Meho, 2006). Thus, email interviews were employed for expert teachers when in-person meetings were not possible.

Data Analysis

This study follows qualitative thematic and content analysis techniques. The analysis of the transcribed interviews was conducted with great care and rigor. The data was repeatedly reviewed to identify the most frequently used words and phrases, which were highlighted to locate the initial codes. After systematically generating these codes, they were compiled into potential themes. The codes were then connected by identifying data connections to generate themes based on similarities, differences, patterns, and structures. A thematic map of the analysis was created to extract the excerpts relevant to the research question analysis. This comprehensive and methodical process allowed for a profound and insightful interpretation of the data, offering substantial insights and valuable contributions to the research domain.

RESULTS

Challenges in Conventionally Environmental Education

This section discusses the findings obtained to answer the first research question: "What are the challenges encountered by students in conventionally environmental education?" Eight students from local university A were chosen from three different departments, including Environmental Engineering, Environmental Science, and Ecology, to address this question. The diversity of the students' backgrounds enabled this study to accumulate a wide range of experiences and viewpoints for a more in-depth analysis. (See Table 2)

Table 2.
Profile of the Students (n=8)

No.	Pseudonyms	Sex (M/F)	Educational level	Affiliated departments		
				EE	Ecol	ES
1	Oliver	Male	Senior	√		
2	Olivia	Female	Sophomore			√
3	Noah	Male	Freshman		√	
4	Emma	Female	Sophomore	√		
5	Sophia	Female	Freshman		√	
6	Elijah	Male	Sophomore			√
7	Ava	Female	Freshman	√		
8	Liam	Male	Freshman	√		

Notes. EE= Environmental Engineering. Ecol=Ecology. ES= Environmental Science

Through the examination, transcription, translation, organization, coding and interpretation of the interview data, five themes were identified within the data: students' lack of environmental knowledge, teacher-centered instructional models, insufficient situated learning, low engagement and interest in learning, and lack of teacher-student interaction.

Lack of Environmental Knowledge

The students have a positive attitude towards environmental protection and have gradually developed good environmental behavior. However, they all feel that their knowledge of the environment is inadequate. Despite their eagerness to study environmental issues in depth and their active participation in courses related to their major, they encounter limitations in their education. They describe experiences where courses only briefly touch upon critical topics or fail to provide a comprehensive framework for understanding, leading to a superficial grasp of environmental issues. This situation is attributed to constraints such as limited class time and structured educational objectives, which prevent in-depth exploration and learning. The students desire a more in-depth and practical approach to environmental education to enhance their knowledge.

Teacher-Centered Instructional Models

Students shared their experiences with teacher-centered teaching models in environmental courses. The lectures' fast pace leaves little time for thorough engagement with the material, underscoring the necessity for additional support mechanisms to assist students in understanding complex topics. They contend that learning is most effective when driven by students' intrinsic motivation, indicating that passive learning, as a result of teacher-centered approaches, may not yield satisfactory outcomes. In addition, they pointed out a scarcity of opportunities to develop skills for independent research and exploration of environmental issues.

Insufficient Situated Learning

The students would like to see more situated learning in environmental education and emphasize the importance of linking theoretical knowledge to real-life situations. They highlight the challenge of engaging with abstract practical content without experience, such as the difficulty of imagining and understanding processes like wastewater treatment without direct exposure. Simulations and starting with familiar, everyday concepts are suggested to make learning more accessible and engaging. Students believe that making education vivid by demonstrating how environmental concepts are integral to their daily lives can significantly enhance interest and learning outcomes.

Low Engagement and Interest in Learning

The students express deep concerns about the low engagement and interest in learning, attributing this to the dull nature of the course content. Teachers are described as serious and responsible but fail to engage students beyond the first two rows, indicating widespread disinterest. The courses' lack of appeal presents a significant challenge. Students highlight a gap between theoretical knowledge and practical application, particularly in addressing real-world issues like nuclear wastewater discharge. This underscores the need for engaging, relevant, and practically applicable environmental education.

Lack of Teacher-Student Interaction

The students highlight the difficulty of receiving personalized attention due to the current teaching and learning models. Addressing individual questions and concerns becomes impractical with large class sizes (about 60 students) and only one teacher available. This issue is particularly challenging for shy students who feel uncomfortable asking questions, resulting in unanswered inquiries. Moreover, the traditional organization of courses limits the efficient use of teaching resources and impedes effective communication between teachers and students, making it difficult for students to thoroughly understand the course material and provide feedback (See Table 3).

Table 3.
Students' Interview Themes and Quotes

Themes	Example quotes
Lack of environmental knowledge	Olivia: *"My environmental knowledge feels superficial. In my first year, I took a microbiology course that briefly covered water quality, which I wanted to explore more deeply. However, limited teaching time meant we only touched on the topic, preventing in-depth study."* Oliver: *"As a senior, my understanding of environmental topics is still basic and lacks depth. We learned about wastewater treatment through formulas and calculations, but I don't have a cohesive understanding—just a mechanical grasp of the principles."* Noah: *"The current environmental courses are too boring, which makes it hard to focus. This lack of engagement has left me with inadequate knowledge of environmental topics."*
Teacher-Centered Instructional Models	Emma: *"Courses are mainly teacher-centered, with rapid instruction that doesn't allow time for reflection. A resource to clarify challenging concepts during lectures would be very helpful."* Olivia: *"The teacher-centered approach fosters passive learning. Motivation plays a key role—students perform better when they're intrinsically motivated, rather than relying on external pressures."* Oliver*: "Though some courses now allow student presentations, teaching is still mostly teacher-centered, with limited encouragement for independent exploration of environmental topics."*
Insufficient Situated Learning	Sophia: *"The abstract nature of environmental education is challenging, like mapping tasks. We've never seen a real water treatment plant, yet we're expected to create blueprints, which makes it hard to understand."* Oliver: *"Situated learning is essential, but large class sizes make real-life visits, like to a sewage treatment plant, impractical. We need classroom simulations to experience real-life scenarios."* Olivia: *"Environmental education should start with everyday concepts to make topics more*

	accessible. When students see the relevance to real life, it sparks curiosity and interest."
Low Engagement and Interest in Learning	Elijah: *"Teachers are responsible, but students lack interest, especially those sitting further back, which affects class engagement and my own mood."* Noah: *"Many students find the courses boring, which is a major obstacle for us."* Liam: *"Environmental courses are dull and often lack practical relevance, like discussions on Japan's nuclear wastewater, which feels disconnected from real-life application."*
Lack of Teacher-Student Interaction	Oliver: *"With one teacher and 60 students, it's hard to address individual questions. Some students are also too shy to ask, keeping their concerns unaddressed."* Liam: *"The large class size limits individual interaction, making it difficult to cater to each student's specific questions or knowledge needs."* Ava: *"Traditional instructional models limit effective teacher-student communication and prevent full use of teaching resources, reducing knowledge transfer and timely feedback from students."*

Opportunities for the Integrating of AI-chatbots in Environmental Education

Based on students' challenges in traditional education, expert teachers have proposed opportunities that AI-chatbots can offer in environmental education. Leveraging these opportunities could potentially overcome the difficulties encountered in traditional education. This section discusses findings from the second phase of the study, which aimed to answer the research question: "What opportunities does the integrating of AI-chatbots in environmental education present?" Semi-structured interviews were conducted with five expert teachers specializing in Environmental Science, Educational Technology, and Artificial Intelligence to address this question. Their diverse backgrounds allowed the study to gather numerous experiences and viewpoints, facilitating a more comprehensive analysis (see Table 4).

Table 4.
Profile of the Expert Teachers(n=5)

No.	Pseudonyms	Position	Sex(M/F)	Educational Level	Experience (Years)	Expertise		
						ES	ET	AI
1	Jasmine	Head of Department Public University	Female	PhD	8	√		
2	Smith	Senior Lecturer& academic leader Public University	Male	PhD	10	√		
3	Brown	Senior Lecturer Public University	Male	PhD	12		√	
4	Wilson	Senior Lecturer Public University	Male	PhD	6		√	
5	Davis	Lecturer Public University	Male	PhD	6			√

Notes. ES= Environmental Science. ET= Educational Technology. AI= Artificial Intelligence

The interview data was thoroughly examined, transcribed, translated, organized, coded, and interpreted, which identified four themes within the data: enhancing learning engagement, creating personalized learning experiences, promoting critical thinking and problem-solving, and improving learning experience and outcomes.

Enhancing Learning Engagement

Expert teachers believe that integrating AI into environmental education provides students with opportunities to promote learning engagement and improve environmental literacy. They highlight that AI facilitates interactive learning through quizzes, simulations, and gamified experiences, making lessons more dynamic and memorable. Additionally, human-AI interactions stimulate student interest and investment in learning, promoting active participation and a deeper understanding of environmental issues.

Creating Personalized Learning Experiences

Expert teachers emphasize that integrating AI in environmental education brings students opportunities to increase personalized learning by tailoring responses to their individual cognitive abilities and knowledge levels. In environmental education, AI can address diverse student needs by adapting content to their learning pace, style, and interests. Additionally, AI enhances student-content interaction and promotes effective teacher-student conversations. Personalized learning with AI ensures that struggling students receive additional support while advanced students are challenged with more complex material, better meeting individual learning needs.

Promoting Critical Thinking and Problem-Solving

Expert teachers highlight that integrating AI into environmental education allows students to develop critical thinking and problem-solving skills. AI can facilitate activities such as analyzing environmental data, debating ethical issues, and developing sustainability action plans, helping students apply their knowledge meaningfully and enhance their analytical skills. A continuous dialogue with AI-chatbots allows students to question information and verify its accuracy, fostering a critical mindset. AI's personalized learning and real-life problem integration enhance students' problem-solving abilities and promote active and engaged learning.

Improving Learning Experience and Outcomes

Expert teachers believe AI integration into environmental education offers students opportunities to enhance their learning experiences and outcomes significantly. AI manages the time-sensitive nature of environmental topics by providing up-to-date information and facilitating self-directed learning based on teachers' requirements. This approach alleviates the workload for teachers and deepens students' understanding. Additionally, AI tools expand students' thinking and cognitive abilities by enabling them to explore unfamiliar topics independently, boosting engagement and confidence. Personalized generative learning from AI tailors content to individual needs, stimulating interest and promoting active learning, ultimately improving learning outcomes and experiences (see Table 5).

Table 5.
Expert Teachers' Interview Themes and Quotes

Themes	Example quotes
Enhancing Learning Engagement	Wilson: *"Integrating AI makes environmental education more interactive, helping students learn through participation. This approach boosts environmental literacy, enhances problem-solving skills, and encourages eco-friendly actions."* Davis: *"Generative AI can use quizzes, simulations, and gamification to improve engagement and retention. Simulating environmental impacts helps students see consequences, making learning dynamic and memorable."* Brown: *"Human-AI interaction increases engagement and interest, making students more invested in the learning process."*

Creating Personalized Learning Experiences	Wilson: *"AI-chatbots support personalized learning by tailoring responses to each student's cognitive abilities, enhancing interaction and effective student-content engagement in environmental education."* Davis: *"AI enables adaptive learning, adjusting content to each student's pace and interest. It can provide extra support for struggling students and more advanced material for those ready for a challenge."* Brown: *"AI-chatbots offer personalized responses and feedback, meeting individual learning needs and promoting tailored learning experiences in environmental education."*
Promoting Critical Thinking and Problem-Solving	Davis: *"AI in environmental education promotes critical thinking through activities like data analysis, ethical debates, and sustainability planning, helping students apply their knowledge and build analytical skills."* Jasmine: *"When AI-chatbots present information that differs from students' prior knowledge, students can question it and verify accuracy, enhancing critical thinking by encouraging active inquiry."* Wilson: *"AI's interactive features and real-life problem scenarios support active learning, fostering critical thinking and problem-solving abilities."*
Improving Learning Experience and Outcomes	Jasmine: *"Generative AI supports environmental education by helping students access up-to-date resources and engage in self-directed learning, which improves their learning experience and outcomes."* Smith: *"AI tools broaden students' cognitive abilities. When teachers pose new questions, students can use AI to explore further, increasing engagement and confidence, ultimately enhancing their learning experience."* Wilson: *"AI boosts learning outcomes by generating personalized content that meets diverse needs, stimulating interest and promoting active learning, which improves both experience and results."*

Suggestions for the Integrating Of AI-Chatbots in Environmental Education

Based on the opportunities AI-chatbots in environmental education can offer, expert teachers further proposed some suggestions for integrating AI-chatbots in environmental education. This section discusses findings from the second phase of the study, which aimed to answer the research question: "What suggestions do expert teachers have for integrating AI-chatbots in environmental education?" Semi-structured interviews were conducted with five expert teachers specializing in Environmental Science, Educational Technology, and Artificial Intelligence to address this question.

Qualitative data analysis identified three key themes: AI as a supplement rather than a replacement, the risk of over-reliance on AI, and the potential for misuse of AI.

AI as a Supplement Rather Than a Replacement

Expert teachers suggest that while AI-chatbots can significantly enhance environmental education through personalized learning, 24/7 accessibility, interactive experiences, democratizing education, and instant feedback, they should complement rather than replace traditional teaching methods. Human connection remains crucial as teachers inspire passion and foster ethical connections to the subject. AI should serve as an assistant or evaluation aid, helping with various tasks and enabling teachers to facilitate learning. This integration enables students to tackle environmental challenges effectively while promoting independent knowledge construction.

The Risk of Over-Reliance on AI

Expert teachers suggest students are not overly dependent on AI, as it is not infallible and can make mistakes. This over-reliance is a concern for many educators. They emphasize the importance of using AI tools under teacher supervision to mitigate negative consequences. While AI can be an effective learning aid, students should be encouraged to critically assess AI-generated results and maintain a balanced approach to learning.

The Potential for Misuse of AI

Expert teachers suggest avoiding the misuse of generative AI, such as over-relying on it to complete assignments. They highlight the need for collaboration with environmental and educational experts to guide proper usage. Concerns about academic plagiarism are raised, emphasizing that AI should inspire thinking rather than be a source of content to be copied. Students should integrate AI-generated content with existing resources thoughtfully and ethically (See Table 6).

Table 6.
Expert Teachers' Interview Themes and Quotes

Themes	**Example quotes**
AI as a supplement rather than a replacement	Davis: *"AI-chatbots can enhance environmental education with benefits like personalized learning, 24/7 access, and instant feedback. However, human connection is essential for inspiring passion and ethical engagement. AI should supplement, not replace, traditional teaching to empower students for environmental challenges."* Brown: *"AI can assist teaching as a tool for support and evaluation, with teachers guiding students in its use. Together, teachers and AI provide scaffolding that promotes independent knowledge construction."*
The risk of over-reliance on AI	Smith: *"Students must understand that they can't fully rely on generative AI. Over-dependence on AI may have negative consequences, as AI can make mistakes. Teachers should encourage supervised use of AI tools."* Wilson: *"AI is a helpful learning aid, but students need to avoid excessive reliance and critically assess AI-generated results."*
The potential for misuse of AI	Wilson: *"AI should support learning, not be misused to complete all assignments. Collaboration with environmental and education experts is key to managing this balance."*

	Jasmine: *"The way students use AI matters to avoid issues like plagiarism. AI should inspire thinking, not be copied; students should integrate AI content thoughtfully."*

DISCUSSION

The results revealed five challenges in traditional environmental education, such as: *a lack of environmental knowledge*, *teacher-centered instructional models*, *insufficient situated learning*, *low engagement and interest in learning*, and *a lack of teacher-student interaction*. The study also proposed four opportunities that AI-chatbots can offer in environmental education, such as: *enhancing learning engagement*, *creating personalized learning experiences*, *promoting critical thinking and problem-solving*, and *improving the overall learning experience and outcomes*. It also presents three suggestions to integrate AI-chatbots in environmental education, for example, *using AI as a supplement rather than a replacement*, *addressing the risk of over-reliance on AI*, and *preventing the potential misuse of AI*.

Integrating AI-chatbots into environmental education offers promising opportunities while addressing student challenges. Expert teachers believe AI-chatbots are engaging and interactive, enhancing learning by personalizing content and applying theoretical knowledge to real-life situations. They recognize AI's potential to provide support and instant feedback, improving critical thinking and problem-solving skills. However, they also acknowledge the risks of over-reliance on AI and potential misuse. Therefore, a balanced approach is essential, where AI-chatbots supplement traditional teaching methods under the supervision of teachers to ensure effective and responsible use.

The findings of this study align with existing literature on the potential roles of AI-chatbots in environmental education. For example, Iku-Silan (2023) found that a chatbot learning model significantly improved learning outcomes and engagement among junior high school students in Taiwan. Cao and Jian (2024) showed that AI-chatbots and VR technology enhanced college students' understanding of environmental issues and promoted conservationist values. Flores et al. (2022) demonstrated a 70.49% increase in recycling knowledge among university students in Peru using a chatbot virtual assistant. Chi (2024) highlighted AI-chatbots' role in fostering pro-environment attitudes and willingness to pay for environmental protection. These studies collectively underscore the transformative potential of AI-chatbots in enhancing learning outcomes, promoting environmental awareness, and encouraging sustainable behaviors.

This study also contributes to the understanding of integrating AI-chatbots in environmental education. It provides empirical evidence on the specific challenges students face in traditional environmental education and opportunities and suggestions for applying AI-chatbots in environmental education. The study also offers a detailed comparison of student and teacher perspectives, highlighting the consensus on the benefits of AI integration and the importance of maintaining a balanced approach. Additionally, it highlights the potential roles of AI-chatbots as a game-changer for environmental education by making it more engaging, interactive, and personalized. Thus, fostering greater environmental literacy and promoting sustainable behaviors.

However, AI is similar to a coin with two sides. It's had great opportunities to bring significant advantages to environmental education, but it also needs to consider the potential negative impacts of AI-chatbots as suggested by expert teachers. Over-reliance on AI can lead to students depending too much on modern technology and may block the development of independent higher-order thinking skills. Additionally, over-misuse of AI, such as using chatbots to complete assignments without genuine engagement, can undermine the educational process and lead to academic dishonesty. These concerns highlight the need for balanced integration, in which AI-chatbots supplement traditional teaching methods rather than replace them.

Based on the study's findings, here are some recommendations for developing an instructional module that integrates AI-chatbots into environmental education: First, it is essential to design AI-chatbot modules tailored to individual student needs, providing appropriate support and challenges for struggling and advanced learners. Additionally, adding fun elements like quizzes, simulations, and game-based activities can get students more involved and make learning more enjoyable. Moreover, ensuring linking learning tasks to real-world environmental issues and practical scenarios helps make the lessons feel more relevant and impactful. Furthermore,

it's crucial to blend AI-chatbots with traditional teaching methods. In this way, it could preserve valuable human interactions while also benefiting from the technological advantages of AI. Finally, it is important to notice that students are reminded not to over-rely on or misuse AI-chatbots, keeping them aware of the appropriate boundaries and encouraging a balanced use of these tools. By following these recommendations, educators can design instructional modules that effectively integrate AI-chatbots, enhancing the overall learning experience and outcomes in environmental education and truly making AI-chatbots a game-changer in environmental education.

IMPLICATION, LIMITATIONS AND FUTURE WORK DIRECTION

Implications

Theoretically, using AI-chatbots in environmental education could change how we teach and learn, moving from traditional lectures to a more interactive, student-focused approach. This aligns with constructivist theories (Piaget, 1930) emphasizing active student engagement and personalized learning experiences. The research shows that AI can facilitate students' deeper cognitive processing and higher-order thinking skills by giving instant feedback and personalized learning experiences. Plus, AI can make lessons more relevant and timelier, connecting them to real-world environmental problems. Practically, educators should incorporate AI-chatbots to create interactive and engaging learning experiences, such as quizzes, simulations, and gamified content, to make environmental education more dynamic and memorable. AI-chatbots should tailor educational content to individual students' learning paces, styles, and interests, providing additional support for struggling students and more challenging material for advanced learners. AI-driven activities should be integrated into the curriculum to encourage students to analyze data, debate ethical issues, and develop sustainability action plans, fostering essential analytical skills. AI-chatbots should complement, not replace, traditional teaching methods, maintaining human-AI interaction alongside teacher-student engagement to inspire passion and foster ethical connections to environmental topics. Educators should guide students on the ethical use of AI, ensuring they critically assess AI-generated content and avoid over-reliance. AI tools should be used under teacher supervision to mitigate potential negative consequences and promote academic integrity.

Limitations of the Study and Future Work Direction

The study focused on a single university. Therefore, future research should include multiple higher education institutions to provide a broader perspective on integrating AI-chatbots in environmental education. Additionally, the study involved only 13 participants (8 students and 5 expert teachers). Future research can involve more students and teachers from different backgrounds to ensure the findings are more broadly applicable. Furthermore, this study utilized a single qualitative method. Future research should employ multiple methods, including quantitative or mixed, to provide a more comprehensive analysis. Moreover, the study concentrated solely on environmental education. Future research should explore the integration of AI-chatbots in other disciplines to understand their broader applicability and impact. This study also focused on the short-term impact of AI-chatbots. Future research should investigate the long-term effects of AI-chatbots on learning outcomes and student engagement. Finally, this study focused solely on AI-chatbots. Future research should examine the combined use of AI-chatbots with other educational technologies to assess their synergistic effects on learning outcomes. By addressing these limitations and exploring new directions, future research can provide deeper insights into the effective integration of AI-chatbots in education, ultimately enhancing learning experiences and outcomes across various disciplines.

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