



Artificial Intelligence-Supported Sustainable Education and Students' Environmental Learning Engagement: The Moderating Role of Environmental Self-Efficacy

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ARTICLE INFO	ABSTRACT
Submission: August 29, 2026 Revised: September 10, 2026 Accepted: September 26, 2026 Available Online: October 06, 2026 Keywords: <i>Artificial Intelligence, Sustainable Education, Environmental Learning Engagement, Environmental Self-Efficacy, Environmental Learning, Higher Education, Educational Technology, Sustainability Education.</i> Corresponding author: Muhammad Faisal Email: mfaisal@nips.qau.edu.pk	This study examined the role of Artificial Intelligence-Supported Sustainable Education in promoting students' Environmental Learning Engagement, with particular focus on the moderating role of Environmental Self-Efficacy. A quantitative cross-sectional research design was used, and data were collected from 389 university students in Pakistan through an adopted structured questionnaire administered online using Google Forms. The collected responses were organized in Microsoft Excel and subsequently analyzed using IBM SPSS Statistics. Pearson Product-Moment Correlation, simple linear regression, and moderation analysis were used to examine the relationships among the study variables. The findings showed that Artificial Intelligence-Supported Sustainable Education was positively associated with Environmental Learning Engagement and significantly predicted students' engagement in environmental learning. The findings further indicated that Environmental Self-Efficacy significantly strengthened the relationship between AI-supported sustainable education and environmental learning engagement. These findings suggest that AI-supported educational environments can provide students with accessible, interactive, and sustainability-focused learning opportunities that may encourage greater participation in environmental learning. The study further highlights that technological support may be more effective when students possess confidence in their ability to understand environmental issues and participate in environmentally relevant learning activities. The study contributes to the emerging literature by connecting AI-supported sustainable education with environmental learning engagement while incorporating Environmental Self-Efficacy as an important individual-level factor. The findings may assist educators, higher education institutions, and policymakers in developing technology-supported sustainable learning environments that encourage active participation, environmental understanding, and meaningful student engagement.

Artificial Intelligence-Supported Sustainable Education

The development of Artificial Intelligence (AI) has changed the field of education and the ways that teaching and learning can be improved. Use of AI in education can be as simple as the use of adaptive resources or as advanced as building learning environments, providing personalized feedback, or offering other data-informed educational supports. In higher education, the use of AI-supported tools is expanding to include academic and other learning-related challenges as well as broader educational and social challenges. Among higher education professionals, Castillo-Martínez et al. (2024) identified AI-based tools and systems as one of the key

strategies to challenge the existing digital divides and promote educational transitions. These tools can help educators identify and resolve digital inequalities in their classrooms. Also, as with other educational innovations, educators must develop their digital and critical competencies in order to make best use of AI in education.

The collaboration of AI with education in achieving sustainable development has gained importance, because education itself has to facilitate attainment of the knowledge and skills in achieving the targets of sustainable development. Using AI in education can help students identify and comprehend information and patterns necessary to address sustainability concerns, use critical thinking to identify patterns to develop technologies to sustainability, and design programs to sustainability. In regard to achieving the sustainable development goals, university students are beginning to identify the both the benefits and challenges of AI (Alamäki et al., 2024).

Sustainable Education and Environmental Learning

Sustainable education involves students' ability to identify environmental problems and participate in solving them through learning. Students need to acquire the tools to help them undertake critical analysis and synthesize knowledge so that they can contribute to the sustainability debate. Though emerging and sustainable development challenges continue to confront nations, many higher education institutions are focusing on enabling students to understand sustainability through 'meaningful' learning. It appears that this trend could enhance students' interest and values towards issues of sustainability (Adib, 2024). For example, it has been shown that active learning improves students' engagement and understanding of environmental education and that such engagement produces positive effects on students' values towards environmental protection and plays a role in fostering environmental concern and stewardship (Science of the Total Environment, 2024).

Moreover, recent studies suggest digital learning environments positively enhance students' attitudes and engagement toward sustainability issues. Therefore, one possible synergy within technological learning environments is the convergence of the values and attitudes on environment and sustainability (Yadav et al., 2022).

Environmental Self-Efficacy in Sustainable Learning

Environmental self-efficacy is students' beliefs regarding their abilities to identify and address environmental problems. It taps into students' sense of control to determine whether they are psychologically equipped to respond to environmental challenges. Students are motivated to act if they understand that they have the ability to contribute to environmental change. The latest body of knowledge has affirmed that self-efficacy is one of the main psychological mechanisms that alter education-related attitudes and behaviors towards the environment and contribute to the achievement of sustainable development goals (Daumiller et al., 2025). Another study has also suggested that University students' self-efficacy in relation to information is important in changing their attitudes and behaviors towards the environment and is positively associated with pro-environmental behaviors (Akakpo et al., 2024).

Self-efficacy may be more relevant when students face complex and tough environmental challenges for which the existing solutions may not be sufficient. Self-efficacy is a sense of efficacy to control environmental challenges through self-instilled belief in one's ability to engage in challenging activities and make changes that are necessary to ensure improvement in complex environmental issues.

Artificial Intelligence, Environmental Learning Engagement, and Environmental Self-Efficacy

Integrating AI in sustainable education is important because AI can make education more interactive and responsive. Related research shows that AI can help students learn more effectively about environmental situations, provide sustainability feedback and help students create solutions. Furthermore, research has shown that AI can help build students' knowledge about the environment and promote more active involvement with the environment (Science of the Total Environment, 2024). However, for AI to be effective, it must be integrated in a meaningful way into teaching and learning activities (Liang et al., 2023). Some research shows that educational experiences centered on sustainability can develop self-efficacy, as well as positively impact environmentally friendly behaviors of students (2025). Since AI-supported sustainable education can positively impact environmental learning engagement, and environmental self-efficacy and sustainability behaviors can be positively impacted by educational experiences, it could be that they are all associated.

Recent studies on the intersection of AI and education cover sustainability education, environmental education, and students' self-efficacy. However, these areas have often been addressed in separate studies. Some studies highlight AI's role in environmental

learning and sustainability, while others underscore self-efficacy and environmental engagement and behavior. However, little to no empirical research has been conducted on the connection between AI-supported sustainable education and students' environmental learning engagement while considering self-efficacy as a moderating psychological factor (Alqurni, 2026).

This study focuses on Artificial Intelligence (AI) Supported Sustainable Education and Students' Environmental Learning Engagement, considering the moderating role of Environmental Self-Efficacy. By combining these variables, this study evaluates if AI-supported sustainable educational experiences and environmental learning engagement are related and if the nature of this relationship depends on students' levels of environmental self-efficacy. This research shows how AI-supported education integrates other psychological factors of students and sustainability-oriented learning and education (Chai, 2026).

Research Objectives

- To examine the relationship between Artificial Intelligence-supported sustainable education and students' environmental learning engagement.
- To assess the relationship between environmental self-efficacy and students' environmental learning engagement.
- To determine the moderating role of environmental self-efficacy in the relationship between Artificial Intelligence-supported sustainable education and students' environmental learning engagement.

Problem Statement

The deployment of Artificial Intelligence (AI) in education allows opportunities to make learning more adaptive and interactive, and more supporting for sustainable development. Integration of AI into context-sensitive educational activities integrated with sustainability offers opportunities to promote awareness of and participation in sustainable development (Hmoud et al., 2025). However, the research concentrates on promoting awareness, participation, and literacy regarding AI with respect to the inclusion of sustainable development in higher education (Fatima et al., 2026). There is scarce research regarding students' environmental learning engagement with AI-supported sustainable education. Sustainability education research conveys that knowledge and attitudes towards the environment may be improved among students, while behavioral changes might lag behind (2024). A different body of research conveys that self-efficacy increases participation and learning outcomes regarding sustainability (Davor et al., 2026). Environmental self-efficacy may alter the level of engagement students have with AI-supported sustainable education with respect to environmental learning. This gap in research is addressed with the current study.

Significance of the Study

The present study is significant because it examines how Artificial Intelligence-supported sustainable education may contribute to students' environmental learning engagement while considering the role of environmental self-efficacy. The study can provide a clearer understanding of how AI-supported educational practices can be used to encourage students' active involvement in environmental learning rather than focusing only on the delivery of environmental information. The findings may be useful for teachers and educational institutions in designing learning activities that integrate AI with sustainability-related content and encourage students to participate more actively in environmental learning. The study may also help educational planners and policymakers understand the importance of students' confidence in their environmental abilities when developing AI-supported sustainability education. Furthermore, by examining environmental self-efficacy as a moderating factor, the study can provide a more comprehensive perspective on individual differences in students' responses to AI-supported sustainable learning. Finally, the study may contribute to the existing academic literature by providing empirical evidence on the combined role of AI-supported sustainable education, environmental learning engagement, and environmental self-efficacy.

Literature Review

Artificial Intelligence-Supported Education for Sustainable Learning

AI has been integrated into the educational process to ensure individual approaches, to give immediate feedback, provide adaptive activities and offer a wide range of educational resources. Strielkowski et al. (2025) noted that AI has the potential to facilitate exploration of sustainability issues through supported-learning environments, and outlined how AI in learning can speed up and individualize the educational process. Kayaalp et al. (2025) examined the role of AI literacy in development education students and pointed out the importance of AI literacy in understanding the roles of AI in the field of sustainable development. AI has the potential to individualize learning at different paces, and facilitate the understanding of difficult concepts, and offer rich information and

learning materials through different digital and online sources. This has the potential to empower students to better learn about environmental and sustainability issues.

While AI technology in education has many potential applications, how effectively it is associated with learning objectives determines the extent to which it can advance education for sustainable development. Issabayeva et al. (2026) report some students understanding the opportunities that AI has for sustainability but still experiencing challenges as a result of having limited understanding of AI and its implications for sustainable development. AI-supported sustainable education should therefore include learning activities that enable students to understand sustainability problems, critically assess the information at their disposal and make choices that point toward sustainable solutions, rather than using AI to simply identify and determine the extent of sustainability problems. Teachers are key to demonstrating how to responsibly integrate AI into learning for sustainability. AI education should aim to equip students with the skills and abilities to make responsible and informed choices about sustainability.

Technology-Supported Environmental Learning

Digital technologies allow students to access different types of environmental data, probe sustainability challenges, and engage in different learning opportunities. As demonstrated by Husamah et al. (2025), digital technologies can help advance students' environmental awareness and provide other approaches for sustainability education. Likewise, a research study published in *Science of the Total Environment* (2022) supports that the use of AI and VR in the classroom can extend students' awareness of environmental knowledge, develop students' care and concern for the environment, and advance students' participation in activities promoting environmental education. These findings are congruent with other studies that have demonstrated how different technologies can extend students' concern and attention toward environmental challenges and help them achieve a deeper understanding of sustainability challenges. As discussed earlier, use of AI in education can provide a learning environment that is personalized, interactive and accessible to students of all ages. Technology-supported learning environments allow students to connect their understanding of environmental concepts and sustainable development to practice (Nacaroğlu & Göktaş, 2025)

There are still challenges in integrating AI and other digital tools to meaningfully advance environmental education. For example, while AI may provide a starting point to environmental education, it may not answer deeper questions related to sustainability and may not explain the underlying frameworks. Additionally, recent research shows that there may be challenges with the contextual relevance and reliability of AI in environmental education. These results support the findings of other studies that the educational value of AI is determined by its link to instructed and clearly defined learning objectives. When critically examined and evaluated by students, technology can promote students' assessment of the adequacy of environmental information, questions raised by students and other challenges that remain concerning the development of students' environmental concern and education (Cheng et al., 2021).

Environmental Self-Efficacy and Learning Engagement

Environmental learning engagement refers to the ways in which students are actively involved in understanding environmental issues by interest, cognitive participation, discussion, investigation and learning activities. Recent studies have shown students are aware of environmental issues, and some of them could get involved with sustainability-related activities. Benzehaf et al. (2025) noted that University students, in general, are environmentally aware and have favorable attitudes concerning environmental issues, and there is a lack of active participation in environmental issues. This suggests that positive attitudes and environmental knowledge are not enough for enhancing learning environments and opportunities for students to be actively involved in environmental issues. Such learning environments and opportunities are necessary for students to understand environmental problems, and do research, and formulate strategies to solve environmental problems by integrating their academic knowledge. The opportunities may be facilitated through the use of AI in learning (Sökmen, 2021).

Environmental self-efficacy refers to a person's confidence to perceive environmental problems, to address those problems and to improve the environment. This concept is closely related to sustainability education. People with confidence in their own environmental abilities may take part in challenging environmental education activities. Bellini et al. (2022) indicate that students in community-engaged environmental learning activities set and prioritized their environmental goals and strengthened their environmental problem-solving self-efficacy. The focus of these studies has mainly been on outcomes linked to self-efficacy. Self-efficacy helps students perceive challenges related to the environment, and determine whether they are capable of responding to those challenges. If students are empowered by learning, then they may take the initiative to investigate, discuss and deal with environmental issues. So, environmental self-efficacy reveals students' engagement and willingness to deal with environmental problems.

AI-Supported Sustainable Education and Environmental Engagement

AI-Supported sustainable education may let students work with sustainability content and environmental problems more. Some features of AI can let students work with individualized content, or immediately provide them feedback. AI can help students with different ways to approach and explore the interactions between complex, interrelated environmental issues. Riandi et al. (2026) showed that AI-related learning can advance students' comprehension of sustainable development. Other recent studies have demonstrated that digital technologies can advance students' interaction with environmental problems in the context of learning and teaching.

The reviewed studies indicate a positive relationship. However, most other recent studies have been more likely to examine AI literacy, sustainability, or environmental awareness and pro-environmental behavior rather than environmental learning engagement. Therefore, the present study addresses a gap in the literature by focusing on environmental learning engagement as the desired educational outcome (Chaudhary, 2026).

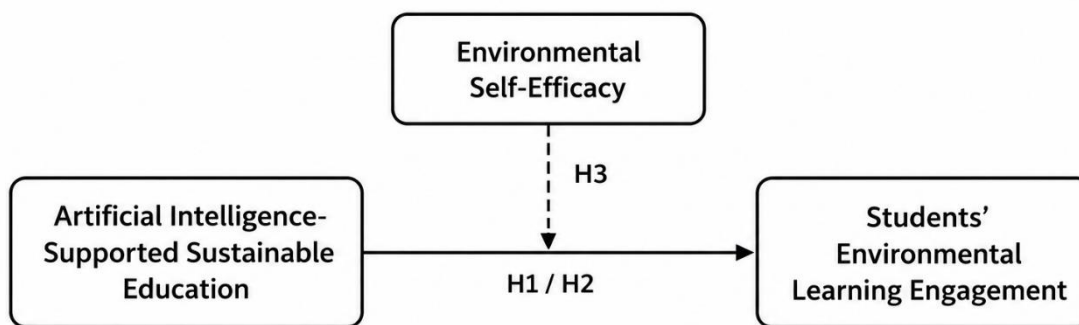
Research Gap

Although recent studies have examined Artificial Intelligence (AI), personalized learning, and sustainable education, limited attention has been given to how AI-supported sustainable education can influence students' engagement in environmental learning. Previous research has mainly focused on AI literacy, general educational applications, environmental awareness, sustainability, and institutional factors (Amer et al., 2026). Similarly, environmental education studies have shown that students may have environmental awareness, positive attitudes, and an interest in sustainability, but this does not always lead to active involvement in environmental learning activities (Huamantupa Mar et al., 2026). Therefore, there is a need for further research to examine whether AI-supported sustainable education can encourage students to become more actively engaged in environmental learning. This study addresses this gap by focusing specifically on the role of AI-supported sustainable education in students' environmental learning engagement. While it has been shown that environmental self-efficacy has a positive impact on students' ability to tackle environmental issues (Al Shaibani et al., 2026) there is scant research on whether environmental self-efficacy affects the relationship between AI-supported sustainable education and students' environmental learning engagement. The current state of knowledge does not show evidence on the moderating effect of environmental self-efficacy concerning sustainability in higher education, leaving a research void and a clear need for an integrated model that uses Artificial Intelligence (AI) in education, concerning psychological aspects of environmental self-efficacy.

Hypotheses

- **H1:** There is a significant positive relationship between Artificial Intelligence-supported sustainable education and students' environmental learning engagement.
- **H2:** Artificial Intelligence-supported sustainable education significantly predicts students' environmental learning engagement.
- **H3:** Environmental self-efficacy significantly moderates the relationship between Artificial Intelligence-supported sustainable education and students' environmental learning engagement.

Conceptual Framework



A quantitative cross-sectional research design was adopted for this study. A quantifiable metric was constructed using a validated and structured questionnaire to assess Artificial Intelligence (AI) supported sustainable education and environmental learning engagement as well as environmental self-efficacy among students. Data were collected from respondents using an online survey, once.

Population

The population of this study consisted of undergraduate students enrolled in public and private universities across Pakistan. To include students from different parts of the country, universities from all four provinces were considered. The selected universities included the University of the Punjab and University of Education from Punjab; the University of Sindh and Shah Abdul Latif University from Sindh; the University of Peshawar and Abdul Wali Khan University from Khyber Pakhtunkhwa; and the University of Balochistan and Balochistan University of Information Technology, Engineering and Management Sciences from Balochistan.

Sampling Technique

A non-probability convenience sampling technique was adopted. Students who could be communicated online and were willing to participate were included. The questionnaire was provided to students from the sampled higher education institutions.

Sample Size

A total of 389 completed questionnaires were included in the final dataset. These responses were collected from university students who successfully completed the online survey and provided all the information required for the study.

Data Collection

The data were collected through an adopted and contextually adapted questionnaire. The items for Sustainable Education were adapted from previous studies focusing on educational practices and students' learning skills. The questions were modified to make them suitable for the context of sustainable and environmental education among university students.

Environmental Learning Engagement was measured using items based on the behavioral and emotional engagement framework. The scale focused on students' persistence, interest, participation, and emotional involvement in environmental and sustainable learning activities. The items were adapted according to the objectives and context of the present study. Environmental self-efficacy was measured using the Environmental Self-Efficacy Scale Short (ESE-10). The scale includes 10 items that assess individuals' confidence in their ability to perform environmentally responsible actions and deal with challenges related to pro-environmental behavior. The items were adapted to suit the context of environmental learning among university students. The questionnaire used a Likert scale to record participants' responses at different levels of agreement. It was prepared in electronic form using Google Forms and distributed through suitable online communication channels. Before completing the questionnaire, participants were informed about the purpose of the study and were asked to participate voluntarily. The collected responses were then organized and prepared for further analysis.

Data Analysis

After the data were screened and coded, the dataset was transferred from Microsoft Excel to IBM SPSS Statistics for analysis. Descriptive statistics were used to summarize the demographic information and main study variables. The reliability of the measurement scales was checked using Cronbach's alpha. Means and standard deviations were also calculated to describe the overall responses of the participants. Pearson Product-Moment Correlation was conducted to assess the relationship among Artificial Intelligence-supported sustainable education, environmental learning engagement and environmental self-efficacy. Simple linear regression was performed to see if Artificial Intelligence-supported sustainable education predicted environmental learning engagement. Moderation analysis was performed to see if environmental self-efficacy changed the relationship between Artificial Intelligence-supported sustainable education and environmental learning engagement. Differences among demographic variables were assessed through independent samples t-test and one-way Analysis of variance (ANOVA). Tukey HSD post-hoc test was performed to assess significant differences among more than two groups.

Table 1: Demographic Characteristics of the Respondents (N = 389)

Demographic Variable	Category	Frequency (f)	Percentage (%)
Gender	Male	202	51.9
	Female	187	48.1
Age	18–22 years	156	40.1
	23–27 years	151	38.8
	28–32 years	57	14.7
	33 years and above	25	6.4
Academic Level	Undergraduate	214	55.0
	Graduate/Master's	128	32.9
	M.Phil./MS	47	12.1
Province	Punjab	154	39.6
	Sindh	94	24.2
	Khyber Pakhtunkhwa	82	21.1
	Balochistan	59	15.2
Previous Exposure to AI-Based Learning	Yes	267	68.6
	No	122	31.4
Previous Participation in Environmental/Sustainability Activities	Yes	231	59.4
	No	158	40.6

Table 1 shows the demographic information of the 389 study participants. Of the total population, 202 (51.9%) were males and 187 (48.1%) were females. With regards to age, the largest proportion, 156 (40.1%) of the respondents were in the 18–22 age bracket and the second largest, 144 (38.8%) of the respondents were in the 23–27 age bracket. Regarding academic level, the largest proportion (55.0%) of the respondents was at the undergraduate level, 125 (32.9%) of the respondents were at the graduate/masters' level, and the remainder, 46 (12.1%) of the participants were at the M.Phil./MS level. Of the participants, 39.6% were from Punjab, 24.2% from Sindh, 21.1% from Khyber Pakhtunkhwa, and 15.2% were from Balochistan. The remaining 8.9% of the participants were from other provinces. Of the participants, 68.6% were exposed to AI-based learning. Of these participants, 59.4% had participated in environmental and/or sustainability activities. Overall, the demographic representation was even across genders, age brackets, academic levels, and provinces. Relevant previous learning experiences were also captured.

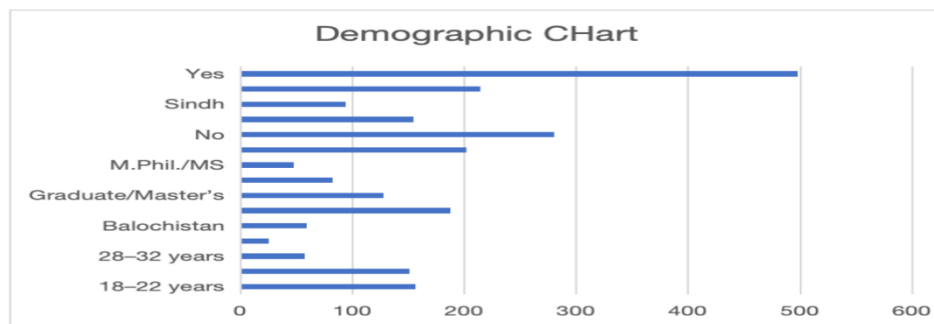
**Fig 2: Demographic characteristics of respondents (N=389)**

Table 2: Reliability Statistics, Means, and Standard Deviations of Study Variables (N = 389)

Study Variable	No. of Items	Cronbach's Alpha (α)	Mean (M)	Standard Deviation (SD)
Artificial Intelligence-Supported Sustainable Education	10	0.91	3.84	0.62
Environmental Learning Engagement	10	0.89	3.76	0.66
Environmental Self-Efficacy	10	0.88	3.81	0.64

Reliability statistics, means, and standard deviations of the study variables are listed in Table 2. Items in the scales showed good to excellent internal consistency as indicated by the Cronbach's alpha ranging from 0.88 to 0.91. Artificial Intelligence-Supported Sustainable Education showed the highest level of reliability ($\alpha = 0.91$), followed by Environmental Learning Engagement ($\alpha = 0.89$) and Environmental Self-Efficacy ($\alpha = 0.88$). The mean scores were 3.76 to 3.84, indicating respondents, in general, had favorable attitudes towards the study variables. The standard deviation scores ranged between 0.62 and 0.66, indicating moderately high levels of variability in respondents' scores.

Table 3: Pearson Product-Moment Correlation Between Artificial Intelligence-Supported Sustainable Education and Environmental Learning Engagement (N = 389)

Variables	M	SD	1	2
Artificial Intelligence-Supported Sustainable Education	3.84	0.62	—	
Environmental Learning Engagement	3.76	0.66	0.62**	—

The Pearson Product-Moment correlation is shown in Table 3. The result shows a positive and statistically significant relationship between the two variables with $r = 0.62$, $p < .01$. This means that Artificial Intelligence-Supported Sustainable Education and Environmental Learning Engagement were positively associated with each other. The correlation was moderate to strong, showing that the practice of artificial intelligence (AI) and sustainable education had a strong positive correlation with students' engagement in environmental learning.

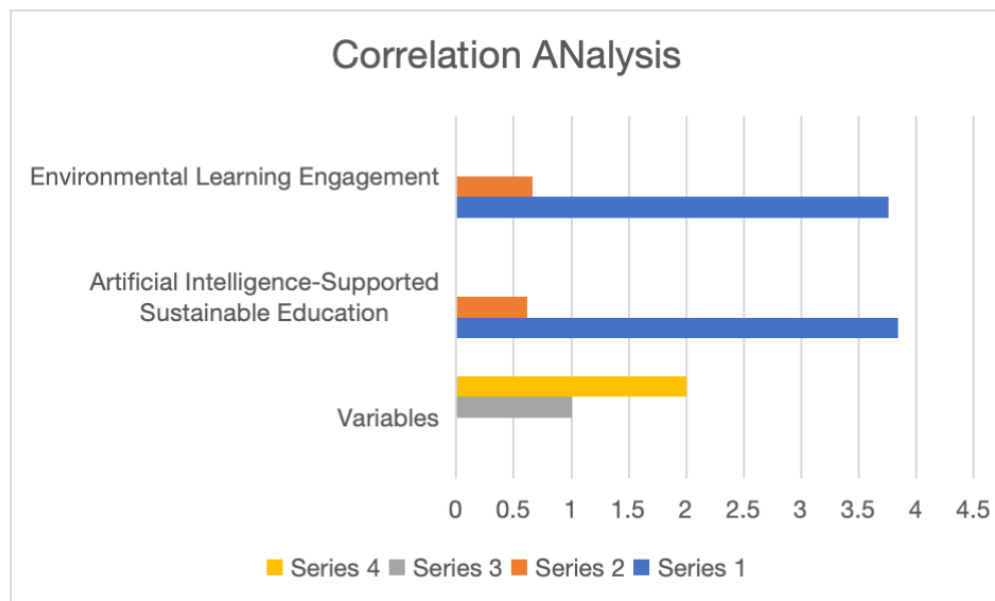
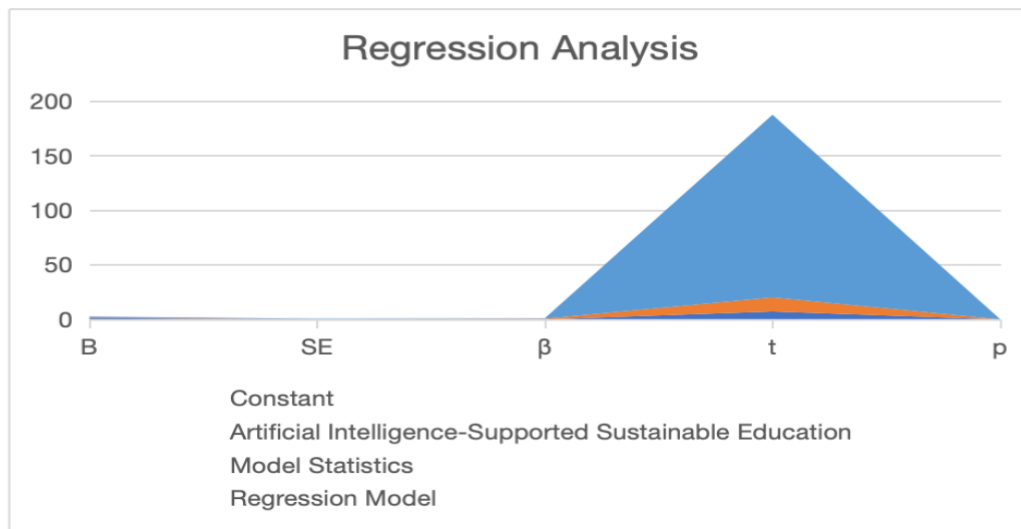
**Fig 3: Correlation Analysis**

Table 4: Simple Linear Regression Analysis of Artificial Intelligence-Supported Sustainable Education Predicting Environmental Learning Engagement (N = 389)

Predictor	B	SE	β	t	p
Constant	1.28	0.18	—	7.11	< .001
Artificial Intelligence-Supported Sustainable Education	0.65	0.05	0.62	12.94	< .001
Model Statistics	R	R ²	Adjusted R ²	F	p
Regression Model	0.62	0.38	0.38	167.45	< .001

Simple Linear Regression results are presented in Table 4. Results show that Artificial Intelligence-Supported Sustainable Education significantly and positively predicted Environmental Learning Engagement ($B = 0.65$, $\beta = 0.62$, $t = 12.94$, $p < .001$). The results also indicated that the model explained 38% of the variance in Environmental Learning Engagement ($R^2 = 0.38$). The findings also indicated that the overall regression model was statistically significant ($F = 167.45$, $p < .001$), hence, supporting the notion that high levels of Artificial Intelligence-Supported Sustainable Education promoted high levels of students' Environmental Learning Engagement.

**Fig 4: Simple Regression Analysis****Table 5: Moderation Analysis of Environmental Self-Efficacy in the Relationship Between Artificial Intelligence-Supported Sustainable Education and Environmental Learning Engagement (N = 389)**

Predictor	B	SE	β	t	p
Artificial Intelligence-Supported Sustainable Education	0.48	0.05	0.45	9.60	< .001
Environmental Self-Efficacy	0.31	0.05	0.30	6.20	< .001
AI-Supported Sustainable Education × Environmental Self-Efficacy	0.16	0.04	0.14	4.00	< .001
Model Statistics	R	R ²	ΔR^2	F	p
Moderation Model	0.70	0.49	0.02	124.50	< .001

Moderation analysis was conducted to examine whether Environmental Self-Efficacy changed the Artificial Intelligence-Supported Sustainable Education and Environmental Learning Engagement relationship. Analysis was carried out on a sample of 389 participants. Artificial Intelligence-Supported Sustainable Education was found to predict Environmental Learning Engagement ($B = 0.48$, $\beta = 0.45$, $p < .001$), and Environmental Self-Efficacy also showed a positive significant association with Environmental

Learning Engagement ($B = 0.31$, $\beta = 0.30$, $p < .001$). The interaction term for Artificial Intelligence-Supported Sustainable Education and Environmental Self-Efficacy was positive and significant ($B = 0.16$, $\beta = 0.14$, $p < .001$), indicating Environmental Self-Efficacy positively moderated the relationship. The model accounted for 49% of the variance in Environmental Learning Engagement. Excluding the interaction term resulted in a 2% loss in variance accounted for. From the sample, it was shown that for students with higher Environmental Self-Efficacy, the relationship between Artificial Intelligence-Supported Sustainable Education and Environmental Learning Engagement was stronger.

Discussion

This study examines the impact of Artificial Intelligence (AI)-based Sustainable Education on students' environmental learning engagement and the moderating role of Environmental Self-efficacy. Overall, the results showed that the use of AI in sustainable education has a positive influence on students' environmental learning engagement, and the results of the regression analysis showed that AI in sustainable education positively predicted students' environmental learning engagement. This means that through the use of AI in education in the field of sustainability and environmental issues, learners are more actively involved in the educational process. This is in line with what (Mehmood et al., 2026) mentioned that AI can be used in an adaptive learning system to promote environmental issues and sustainable development. Also, Kim (2025) reported that when used in the context of sustainable development, learners positively evaluated the use of AI in education in their studies.

The strong positive impact of Artificial Intelligence-Supported Sustainable Education on Environmental Learning Engagement indicates that AI offers opportunities to learn in ways that actively engage students in learning environmental issues. Other advantages of using AI in education to promote self-regulated learning of environmental issues have been reported in different studies (Beyazhancer & Demir, 2025). This positively influenced students' perceptions of the use of AI learning tools in relation to sustainability and educational practices.

This indicates that the relationship was not as simple as a casual acquaintance; rather it reveals that variation in the extent to which students engaged with AI in supporting sustainable education was accompanied by meaningful variation in students' environmental learning. Faiz et al. (2026) also found similar results in their systematic review and bibliometry on the contribution of AI to Sustainable Education. Further, in their recent article, Bipasha et al. (2025) argue that AI has the potential to improve academic processes, consequently creating a more responsive learning environment to the challenges of sustainability, and contribute to Responsive Higher Education in the field of sustainable development, among others. The research also showed that Environmental Self-Efficacy enhanced the relationship between Artificial Intelligence-Supported Sustainable Education and Environmental Learning Engagement. This is valuable because engaged environmental learning is driven by both the students' knowledge and the self-efficacy to identify and respond to environmental challenges. Findings in environmental education reinforce this line of thought. A recent study that investigated Eco paralysis stated that learning that is community-engaged made students more confident in their ability to identify and understand environmental problems and increased students' environmental problem-solving self-efficacy as well as their goal directedness to solve environmental problems. This shows that in order to move students' environmental concern to action, stronger environmental self-efficacy is required (Katalinic et al., 2026).

Thus, the moderating role of Environmental Self-Efficacy can be explained as students' belief in their ability to assess and evaluate environmental challenges. Students with high levels of Environmental Self-Efficacy are more likely to analyze AI-generated environmental data and information. In contrast, Students with low Environmental Self-Efficacy may have limited ability to interpret and evaluate AI-generated environmental data. Interpreting AI is required in both situations. This is in line with recently published evidence that self-efficacy and technology integration can influence and interact with engagement in educational settings. Further evidence from students in Pakistan emphasized the role of psychological confidence and engagement with the interaction of technology and self-efficacy in learning (Dickerson, 2026).

Conclusion

This study found a positive association between Artificial Intelligence-Supported Sustainable Education and students' Environmental Learning Engagement. The findings suggest that students who had greater exposure to AI-supported sustainable learning were more actively involved in environmental learning activities. AI-supported learning can help students explore environmental issues, access useful information, and take greater interest in sustainability-related topics. Overall, the study indicates that the effective use of AI in sustainable education can encourage students to become more engaged in environmental learning. The regression results also found that AI-supported sustainable education positively predicted environmental learning engagement, thus suggesting the use of AI in education related to sustainability to enhance students' participation and interest in

environmental learning. The positive association of AI-supported education in the area of sustainability suggests that this area of education is still not very engaging or interactive for students and the use of AI in education can further improve sustainability learning in an interactive and user-friendly way for students.

Future Implications

Future studies should further examine the use of Artificial Intelligence-Supported Sustainable Education in environmental learning among students from different educational settings and backgrounds. Researchers can conduct studies with students from different regions, academic levels, and types of institutions to gain a broader understanding of this area. Longitudinal studies can also be used to observe changes in students' environmental learning and engagement over a longer period. Experimental studies may provide stronger evidence about whether AI-supported learning can improve students' environmental knowledge, engagement, and behaviors. Such research can help educators understand how technology can be used more effectively to support environmental learning and sustainable practices. Researchers may also consider other psychological and pedagogical factors, e.g. digital literacy, motivation, critical thinking, and environmental awareness to widen the scope of analysis on students' engagement in sustainability education. Educational institutions may foster students' Environmental Self-Efficacy by developing students' skills to utilize information and communication technologies (ICT) in environmental activities, e.g. through problem-based learning, AI-supported projects and environmental activities.

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