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Digital Learning Approaches for Improving Environmental Science Education and Climate Change Awareness Among Students

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Abstract

Environmental education is an important means of developing climate literacy skills and helping students deal with the existing sustainability problems that emerge, including global warming, loss of biodiversity, pollution, and degradation of ecosystems. Nevertheless, traditional methods of educating on environmental science do not offer sufficient practical experience, lack student engagement, and fail to give learners a chance to comprehend complex climate mechanisms through interaction. This study focuses on assessing the effectiveness of digital learning methods as a tool for improving environmental science knowledge and climate change awareness in students. A quantitative experimental design was used through the

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pre-test/post-test method with 200 participants, who were undergraduate students who were engaged in an eight-week digital learning intervention. The proposed method comprised online learning techniques, digital content, simulation exercises, virtual environmental experiments, and online assessments. The results revealed a significant improvement in learning outcomes since there was an increase in environmental knowledge from 66.2% to 91.5% using digital learning. There was also a significant improvement in the climate awareness indicators: climate risk awareness, which increased from 62.5% to 89.6%; sustainability practices, which improved from 58.7% to 87.4%; and environmental responsibility, which increased from 64.3% to 91.2%. Analysis of the students' engagement proved high efficiency; the level of content engagement was 92.4%, learning satisfaction 90.8%, knowledge acquisition 88.9%, and participation 91.6%. The comparative assessment proved that the digital learning model proposed performed much better in terms of knowledge gain (91.5%), engagement (91.6%), and awareness (92.4%) than conventional and online learning approaches.

Keywords:
Digital learning, environmental science education, climate change awareness, e-learning, sustainability education, student engagement.

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Introduction

With regard to environmental threats like climate change, loss of biodiversity, pollution, and ecosystem damage, the demand for scientifically knowledgeable students who can deal with sustainability problems has become greater. Environmental science education is extremely important for increasing awareness about ecology and achieving sustainable development objectives. However, conventional learning approaches are not effective in terms of providing little hands-on experience, limited access to environmental data, lack of motivation on the part of students, and problems with the visualization of climate dynamics (Monroe et al., 2019).

The fast evolution of digital technologies brings new possibilities for making environmental education better through digital learning approaches, such as online learning, interactive simulation, multimedia materials, and virtual environmental experiments. Technologies like learning management systems, virtual field trips, mobile learning apps, and environmental games have shown their effectiveness in improving environmental literacy and climate change awareness (Senese et al., 2026; Ismatullaeva et al., 2026). Still, current digital learning approaches do not have an evaluation framework that can estimate the effectiveness of digital learning approaches in terms of increasing environmental literacy, climate change awareness, and student engagement. Thus, this research is aimed at solving the problem of ineffective traditional environmental learning practices by evaluating digital learning approaches in terms of environmental science education and climate change awareness.

Research Contributions

1. Develops a digital learning framework for environmental science education.
2. Evaluates the relationship between digital learning exposure and climate awareness.
3. Provides recommendations for technology-based sustainability education.

This paper is structured as follows: Introduction, Background, Challenges, Objectives, and Contributions are outlined in Section 1 of this study. Related works in digital learning and environment education are mentioned in Section 2 of the study. Materials & Methods section includes the design of the study, methodology, framework, and evaluation metrics in Section 3. Results & Discussion are mentioned in Section 4 of this study. The conclusion of this study is presented in Section 5.

Related Work

According to systematic reviews, digital technologies increase accessibility, engagement, and knowledge acquisition in the context of environmental education (Hajj-Hassan et al., 2024; Husamah et al., 2025). The

inclusion of sustainability topics in special fields of education has shown the growing importance of linking environmental conservation with professional results (Khalikova et al., 2024; Nasseri & Dehnavi, 2015). Climate education methods have been shown to promote the improvement of climate awareness and behavior in learners (Monroe et al., 2019). Digital transformation techniques have facilitated the analysis of climate change, environmental monitoring, and interactive learning through the understanding of complicated ecological processes effectively (Dudar et al., 2023). In addition to that, including climate education in science curricula has made positive contributions towards the environmental awareness and sustainability-oriented thinking of students (Puspitasari, 2025). Moreover, online collaborative learning frameworks have helped in developing environmental literacy through real-world environmental and scientific learning experiences (Herlanti et al., 2025).

Despite the effectiveness of digital strategies in the success of environmental education initiatives, many barriers exist concerning digital accessibility, equality of education, curricular incorporation, and readiness of teachers (Arasuraja, 2026). The use of effective pedagogical approaches towards sustainability requires the integration of digital tools, real-world activities, and community-based learning approaches (Agbor et al., 2025). Collaboration of educational facilities and industries has been identified as a method for cultivating the competencies and future environmental skills among students (Smitha et al., 2025). Further, innovative methods such as policy analytics, environmental governance, and interdisciplinary learning can enhance awareness and environmental responsibility (Tandi & Shrirao, 2025). Strategies of digital and financial innovations have also been found to be supportive approaches towards sustainable development through education and awareness creation (Selvaraj, 2026).

While there has been research on digital technologies, immersive technologies, and sustainable education techniques, there is a dearth of research examining the influence of these on environmental knowledge, climate change knowledge, and student engagement. The development of an approach that brings together digital learning techniques and educational performance measures is still underdeveloped.

Materials and Methods

Study Design

For this study, a quantitative experimental research design is used to assess how effective digital learning methods are for increasing knowledge and awareness about environmental science and climate change among students. A pre-test and post-test design is applied in order to capture any differences that occurred before and after the application of the digital learning method. The study analyzes how technology-based learning techniques such as the use of simulations, digital content, and online tests can affect the learning outcomes of the learners.

Participants and Data Collection

This experiment was conducted on 200 undergraduate students through an eight-week digital learning program, which dealt with environmental education and climate change awareness. Responses to these tests were recorded in the form of a structured questionnaire that included environmental knowledge tests, climate awareness surveys, and engagement measures. These students were evaluated both pre- and post-intervention in order to evaluate their improvements in the aspects of knowledge acquisition, environmental perceptions, and learning engagement.

Proposed Digital Learning Framework

The digital learning framework that is being developed comprises four main modules that will help to improve environmental science learning. The digital content module will provide environmental videos, interactive lectures, and digital textbooks for better understanding of concepts. The simulation learning module will include climate modeling, pollution simulation, and ecosystem visualization for practical learning. The virtual assessment module will include online quizzes, learning analytics, and automated feedback tools to assess the learning progress of the learners. The awareness evaluation module will measure climate change perception and sustainability behavior through assessments.

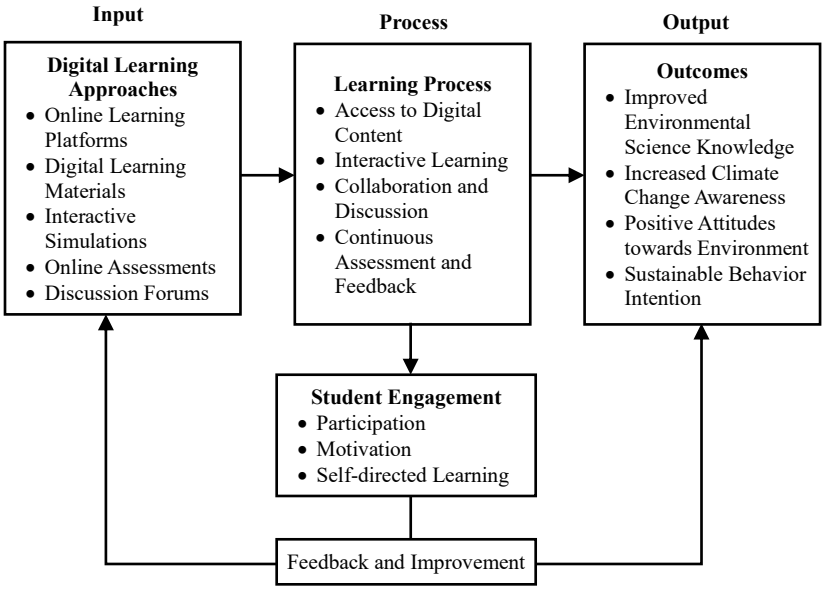

Figure 1. Conceptual framework of digital learning approaches for environmental science education

Figure 1 represents the conceptual framework for the relationship between digital learning inputs, the learning process, and educational outputs. Digital learning methods include online learning systems, digital learning content, simulation exercises, and tests to facilitate the interactive learning process and feedback. The conceptual framework shows how the above elements contribute to environmental science learning, climate change understanding, and sustainability behavior intentions.

Evaluation Metrics

The knowledge improvement, awareness improvement, and students' engagement shall be considered for the effectiveness assessment of the proposed approach for digital learning. The knowledge improvement (KI) is calculated as the percent increase in the comprehension of environmental sciences from pre-test to post-test results. The awareness improvement (AI) shall be assessed through evaluation of the level of awareness of the students on climate change. The Student Engagement Score (SES) is defined by participation and interaction in digital learning activities (Equations 1 – 3).

$$\mathrm{KI} = \frac{\mathrm{Post-test-Pre-test}}{\mathrm{Pre-test}} \times 100 \quad (1)$$

$$\mathrm{AI} = \frac{\mathrm{A_{post} - A_{pre}}}{\mathrm{A_{pre}}} \times 100 \quad (2)$$

$$\mathrm{SES} = \frac{\sum \mathrm{Engagement\ Scores}}{\mathrm{Maximum\ Score}} \times 100 \quad (3)$$

Result & Discussion

Improvement in Environmental Knowledge

Effectiveness of digital learning was determined by the comparison of pre-test and post-test results of the environmental knowledge test. It is evident from the results displayed in table 1 that digital learning was more effective for gaining knowledge than traditional ways of teaching. Learners' scores in digital learning improved from 66.2% to 91.5%.

Table 1. Environmental knowledge improvement analysis

Learning Approach	Pre-test (%)	Post-test (%)
Traditional Learning	65.4	72.8
Digital Learning	66.2	91.5

Climate Change Awareness Analysis

The effects of digital learning on the awareness of climate change were studied based on three primary parameters, namely: climate risk perception, sustainability, and environmental responsibility. As can be seen from table 2, there was a great improvement in the performance of the students who undertook digital learning experiences.

Table 2. Climate change awareness improvement

Awareness Parameter	Before (%)	After (%)
Climate Risk Understanding	62.5	89.6
Sustainable Practices	58.7	87.4
Environmental Responsibility	64.3	91.2

Student Engagement Evaluation

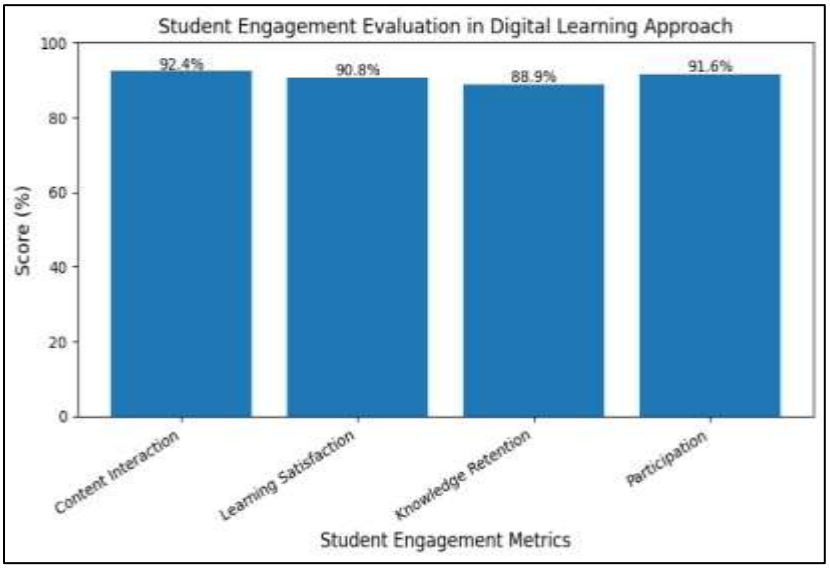

Figure 2. Student Engagement Performance Analysis

The measure of engagement for the students was done based on content interaction, learning satisfaction, knowledge retention, and level of participation. From the results presented in figure 2 above, it is clear that the engagement score was very high since content interaction was recorded at 92.4% while participation was at 91.6%.

Comparative Analysis with Existing Approaches

The suggested digital learning method was compared to the traditional teaching methodology and e-learning technique. The comparative results shown in table 3 reveal that the highest knowledge gain (91.5%), engagement (91.6%), and awareness (92.4%) were obtained through the suggested method. It is clear that incorporation of interaction in learning, simulation, and assessment yields superior education than traditional approaches.

Table 3. Comparative analysis of learning approaches

Method	Knowledge Gain (%)	Engagement (%)	Awareness (%)
Conventional Teaching	72.8	70.5	73.2
Online Learning	84.6	82.4	85.1
Proposed Digital Approach	91.5	91.6	92.4

Conclusion and Future Scope

In this paper, the efficiency of digital learning approaches to improve environmental science learning and awareness of climate change among students has been analyzed. The results proved that technology-assisted learning approaches are an effective alternative to conventional environmental education because they facilitate knowledge acquisition, awareness building, and engagement. The experimental testing with 200

undergraduate students proved that the level of environmental knowledge rose from 66.2% in the pre-test to 91.5% after implementing digital learning approaches. Similarly, there were considerable changes in climate awareness parameters: climate risks awareness increased from 62.5% to 89.6%, sustainability practices from 58.7% to 87.4%, and environmental responsibility from 64.3% to 91.2%. Engagement analysis confirmed the efficiency of the suggested approach, providing the following scores: 92.4% for content interaction, 90.8% for learning satisfaction, 88.9% for knowledge retention, and 91.6% for participation.

From the results, it is clear that the digitalization of education is a vital tool that can enhance climate literacy through the provision of interactive digital environments in terms of digital content, simulations, virtual experiments, and a continuous assessment process. The strategies will facilitate learners to have a better understanding of the environmental processes and to adopt sustainability attitudes. Although there are many benefits of digitalizing the learning process, some challenges such as digital access, internet dependency, and the need for teacher training should be taken into consideration.

Future studies might involve the development of artificial intelligence-based personalized environmental learning systems to have an adaptive learning experience based on personal requirements. Moreover, virtual reality-based ecological simulations can be considered for the development of environmental learning environments. Furthermore, the use of IoT-based environmental monitoring data will be useful to make learners' experience based on the current ecological situation. Finally, large-scale studies from different regions are essential to validate the results.

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