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Review Paper

E-learning to Enhance Environmental Literacy in Primary School: A Comprehensive Structured Review

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Abstract: This systematic literature review investigates how e-learning can enhance environmental literacy among primary school students. Environmental literacy is important because it helps young learners understand ecological issues and practice sustainable behaviours. However, traditional teaching methods often fail to engage students effectively in environmental topics. This review focuses on how digital learning tools and platforms can overcome these challenges. A thorough search of recent academic studies was conducted using trusted databases, such as Scopus, Web of Science, and ERIC. The research followed the PRISMA framework to ensure a structured and reliable process. From the databases, 32 relevant articles were selected for final analysis. After screening the databases, 32 relevant publications were chosen for in-depth analysis. The outcomes were then divided into three centrals themes: (1) E-learning and technology integration for environmental and STEM education, (2) Student engagement and learning effectiveness in online education, and (3) Approaches and challenges in distance learning. The reviewed studies indicated that e-learning tools had a positive impact on students' environmental literacy. In particular, students using digital platforms demonstrated an average 25% improvement in knowledge retention and their ability to apply what they learnt. These results suggest that e-learning not only increases student motivation but also improves understanding of complex environmental concepts. Therefore, integrating technology in primary education is a promising step toward building a generation that is more aware and responsible toward the environment.

Keywords: E-learning; environmental literacy; student engagement; interactive modules; STEM education

Introduction

In current times, when environmental problems are becoming more serious, it is very important to improve environmental literacy among young students. Environmental literacy means having the knowledge, skills, and right attitudes to understand and solve environmental issues. This is essential to help young people grow into responsible citizens who can support sustainable development said by Ariyatun et al. (2024). Wu et al. (2020) and Ferreira et al. (2021). However, traditional teaching methods often do not attract students' interest and are less effective in dealing with the fast changes in environmental science. Because of this, new teaching approaches are needed to connect knowledge with real action. One such approach is e-learning, which is a modern educational method using digital tools to make learning more interactive and engaging Bhattacharya and Nath (2016).

E-learning systems include multimedia components like videos, animations, simulations, and quizzes. These tools support different types of learners and help explain difficult environmental topics in a simple way. E-learning also gives flexible and immersive learning experiences, which can improve the quality of environmental education Nurulita et al. (2022), Hanim (2020) and Ahmed (2022). This method suits today's students, known as digital natives, who are used to technology and enjoy interactive learning styles. By using digital platforms, teachers can connect better with students and help them understand environmental topics more deeply.

E-learning also allows easy updating of educational materials, making them more relevant to present-day and local environmental problems Andriopoulou et al. (2022). Because environmental education needs to reflect ongoing scientific changes, e-learning is helpful in offering current, customized content for learners. Research supports the success of e-learning in improving environmental literacy. Studies find that students using digital learning methods learn and remember more than those using traditional methods said by Eom (2021), Eom and Ashill (2018) & Barbera and Clarà (2012). E-learning also provides practical experiences like online field trips and simulations, which help students understand environmental problems through real-world practice. These activities improve critical thinking and long-term understanding. Also, e-learning supports trends in education like personalized learning and developing 21st-century skills said by Marouli (2021). Bacalod (2021) and Baran et al. (2021). As the world becomes more complex, innovative education methods like e-learning are needed to help students face future environmental challenges with knowledge and confidence by Stavreva Veselinovska (2022)

Literature Review

The integration of e-learning into the education system has demonstrated strong potential in improving environmental literacy among students. For example, Pesch et al. (2022) introduce a learning suite called "senseBox and openSenseMap," which blends hands-on physical computing with a simple visual programming interface. This toolkit helps students improve their skills in computing, data handling, and scientific thinking. It combines do-it-yourself (DIY) hardware sensors with a user-friendly coding environment and an open platform to share environmental data. This way, students can take part in real-life projects in environmental education and citizen science, showing the benefit of active and practical learning. In another study, Konig and Schabio (2022) explore digital storytelling in Teaching English as a Foreign Language (TEFL) and literature classes as a way to teach sustainability. Their research shows that 'green stories' which build empathy and critical thinking can be supported through creative tasks like video interviews and virtual reality room design. This method uses tools from literature, performance arts, and environmental education, proving the multidisciplinary power of e-learning.

Furthermore, Nascimento et al. (2024) examine technostress among higher education teachers (HETs), highlighting both the positive and negative sides of using digital tools in education. The use of such tools increases relevance and engagement for students in daily life. In the study by Gupta (2023) smart technologies like AI,VR and game-based learning are studied in schools from developing countries. The findings show that smart platforms not only support high-quality education and digital skills but also help with environmental goals. Audiovisual media is another useful resource. For example, Melendo Rodríguez-Carmona & Gallardo-Camacho (2023) report how private groups in Spain use educational videos to increase environmental awareness. Similarly, Xing and Wang (2022) examine how higher education students use big data and learning analytics to support their learning. Ignacio et al. (2023) present an e-learning module in the Philippines that teaches climate change using systems thinking. This module, checked by field experts, aims to help students understand the connection between human actions and climate change. Gamification is also an effective strategy. Sukmana et al. (2022) explain how game-based learning increases motivation and encourages students to separate waste properly. Through fun activities, students also learn responsibility and discipline, which are important for the environment. This supports the findings by Oerther (2023), who show that community-based projects in engineering education can improve students' understanding of environmental health, like antibiotic resistance.

Moreover, Duda (2023) argue that well-designed mobile apps can influence users to adopt eco-friendly habits. User feedback shows that digital tools, when designed properly, support environmental learning goals. Developing strong education standards is also necessary. Love et al. (2023) describe how environmental topics were included in the technology curriculum in Pennsylvania, aiming to build both engineering and environmental literacy. Zhang and Yan (2024) stress that environmental protection should be a key part of the curriculum for achieving sustainable development goals (SDGs). Although e-learning has many benefits, some challenges still exist. For example, Liu (2022) explore how the metaverse can create detailed environmental simulations that help promote eco-friendly behaviour. Studies from Denys and Klimczuk (2022), Shuai et al. (2024), Kim et al. (2024), Zhang et al. (2020) and Ly et al. (2024) all support that digital tools, multimedia, and big data improve learning outcomes and engagement. These findings show that e-learning is a powerful tool for transforming environmental education, making it more practical, meaningful, and better prepared to help students face environmental problems in the future

Methodology

1. Identification

This study used several key methods in the review process to find enough suitable literature for the analysis. After choosing the main keywords, similar terms were searched by using dictionaries, thesaurus, encyclopaedias, and past research. Then, search strings were prepared and used in Scopus, Web of Science, and ERIC databases with all related keywords included (see Table 1). In the first stage of the review, a total 315 publication were successfully found form these databases.

Table 1. The search string

Database	Search string
Scopus	(TITLE-ABS-KEY((("e-learning*" OR "distance learning*") AND (environmental OR coincidental OR surrounding) AND (literacy OR culture OR learn))) AND ALL(school OR academy)) AND (LIMIT-TO(PUBYEAR,2022) OR LIMIT-TO (PUBYEAR,2023) OR LIMIT-TO (PUBYEAR,2024) AND (LIMIT-TO (DOCTYPE,"ar")) AND (LIMIT -TO (LANGUAGE, "English")
Web of Science	((e-learning OR distance learning) AND (environmenta0l OR coincidental OR surrounding) AND (literacy OR culture OR learn) AND(school OR academy)) (Topic) and 2024 or 2023 or 2022 or 2021 or 2020 (Publication Years) and Article (Document Types) and English (Languages)
ERIC	(("e-learning" OR "distance learning) AND (environmental OR coincidental OR surrounding) AND (literacy OR culture OR learn) AND (school OR academy))

2. Screening

In the screening stage, all selected research materials were examined in the detail to make sure they fit with the focus and purpose of the study questions. Key criteria utilized in this phase involve the selection of research materials relevant to augmenting environmental literacy via E-learning within educational settings. Duplicate papers are expunged, resulting in the exclusion of 240 publications during the initial screening, while 75 papers are subjected to evaluation in the subsequent stage based on a variety of inclusion and exclusion criteria specified in Table 2. This study focuses on the various types of literature such as journal articles, reviews, metanalysis, books, chapters and conference papers that have not been discussed in recent research, with a particular focus on English-language publications spanning from 2020 to 2024. It is noteworthy that one publication was dismissed owing to duplication

Table 2. The selection criterion is searching

Criterion	Inclusion	Exclusion
Language	English	Non-English
Time line	2000-2024	< 2020
Literature type	Journal (Article)	Conference, Book, Review
Publication Stage	Final	In Press

3. Eligibility

After applying all the inclusion and exclusion criteria, the final set of articles for review was determined. Because readers cannot directly know which specific studies support each conclusion, it is important to clearly present the full list of selected research articles included in the final analysis. The systematic review process produced several important outcomes. At the eligibility stage, a total of 74 articles were initially considered. In this phase, each article's title and relevant sections were carefully examined to confirm that they met the established inclusion standards and were aligned with the research objectives of the present study. As a result of this screening, 42 articles were excluded because their titles and abstracts did not show a strong or direct connection to the purpose of the research, based on clear evidence. In the end, 32 articles were retained and used for full analysis in this review.

4. Data Abstraction and Analysis

This research used integrative analysis as the main method to review and combine different reteach types, such as quantitative, qualitative and mixed approaches. The objective of this proficient investigation was to identify pertinent topics and subtopics. The process of theme development began at the early stage of the data collection. As shown in Figure 1, the authors carefully examined 32 selected articles to take out information related to research topic. After that, they reviewed important studies on e-learning and environmental literacy by looking closely at the methods and results from each paper. Themes were created by the author and co-authors based on study evidence, while notes were kept recording analysis steps, ideas and possible questions. Any differences in the themes were found by comparing results and all disagreements were solved through group discussion. The resultant themes underwent refinement to ensure consistency. In the final stage, the identified themes were slightly refined to maintain consistency across the analysis.

To verify the accuracy of the issues presented, evaluation was conducted by two subject matter experts- one in oncology and the other in biomedical science. This expert review process helped to confirm the clarity, relevance and sufficiency to each sub-theme by ensuring content validity within the respective domains. The questions are as follows below: 1) What factors influence students' satisfaction, motivation, and learning effectiveness in online education, and how can personalized learning approaches and assignment designs enhance self-regulated learning and engagement across different disciplines?2) What factors influence students' satisfaction, motivation, and learning effectiveness in online education, and how can personalized learning approaches and assignment designs enhance self-regulated learning and engagement across different disciplines? 3) How do immersive game environments and mobile devices enhance learning outcomes and engagement in distance education, and what are the key barriers, facilitators, and global implications of varying technologies and legal regulations across countries?

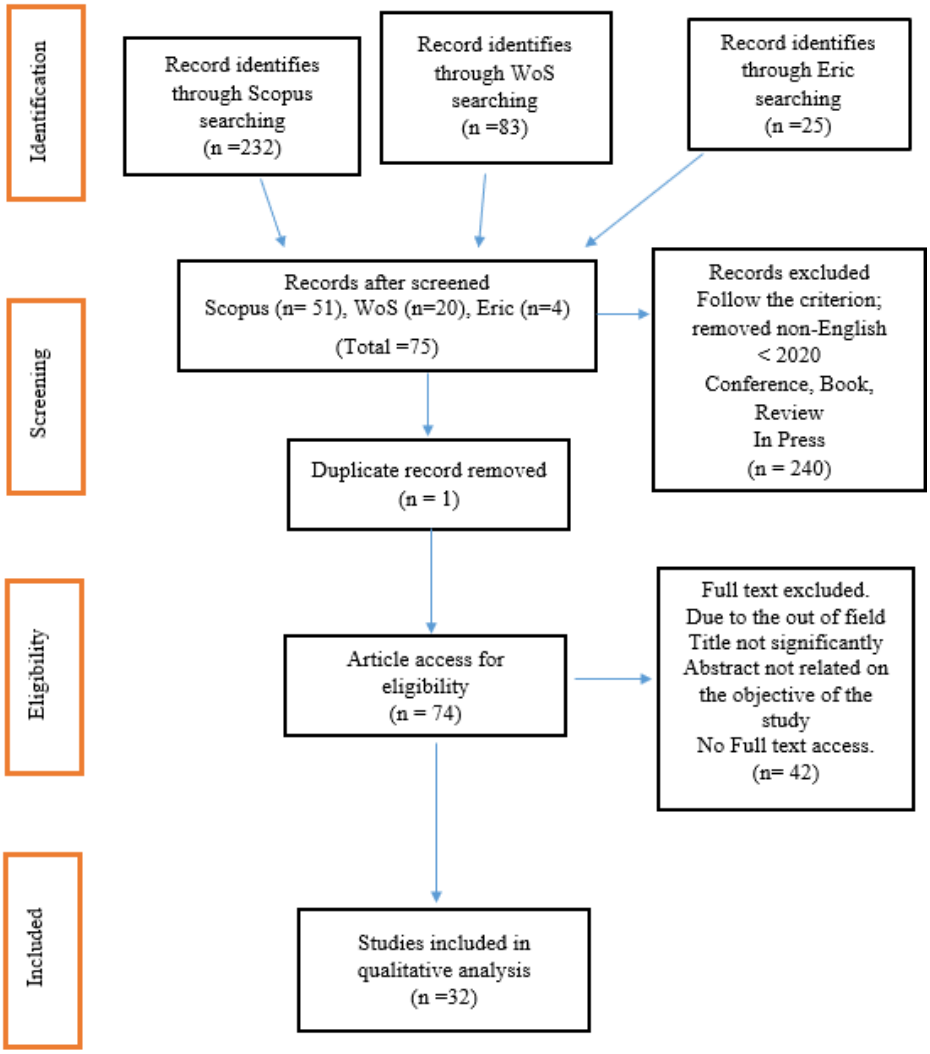

Figure 1. The flow chat used in the search process for this study

Result and Discussion

This part of the paper presents the result findings along with a full discussion based on the results.

1. E-Learning and Technology Integration for Environmental and STEM Education

The integration of e-learning tools and technology in environmental and STEM education has shown significant promise in enhancing student learning outcomes and engagement. A useful way to apply technology in teaching environmental science is by using online platforms for community and citizen science activities. Herodotou et al. (2022) investigated the participation of young people in online citizen science projects hosted on the Zooniverse platform. E-learning tools have also been explored in higher education settings to promote sustainability literacy. Perbandt et al. (2021) conducted a study on the effectiveness of various e-learning tools in a course on participatory processes in environmental politics. The study highlights the need for well-designed e-learning models that can enhance sustainability education in higher education Mikhailova et al. (2021) Incorporating ecosystem services (ES) into STEM education is another approach that has been shown to be effective. Mikhailova et al. (2021) integrated ES concepts into an online soil science course, using reusable learning objects (RLOs) to teach students about soil organic carbon and its environmental and economic implications This approach not only connected theoretical knowledge with real-world applications but also enhanced students' appreciation of the environmental and

societal importance of soil resources Mikhailova et al. (2022). Furthermore, augmented reality (AR) technology has been identified as a valuable tool in science education for improving environmental literacy and self-regulation skills. Arici (2024) examined the impact of AR on fifth-grade students and found that AR-supported learning environments significantly enhanced students' environmental sensitivity, positive behaviours, and knowledge Kuruppuarachchi et al. (2021) explored this approach with junior high school students studying environmental change. The study found that the discovery learning model, facilitated by e-learning, encouraged active, independent, and enthusiastic learning, although critical thinking skills remained low overall. This highlights the need for continuous improvement and adaptation of e-learning strategies to effectively foster critical thinking in environmental education by Chusni et al. (2020).

The integration of e-learning tools and technology in environmental and STEM education has shown significant promise in enhancing student learning outcomes and engagement. Studies have highlighted various approaches and their impact on different aspects of education, from environmental literacy to critical thinking skills. One effective method is through online community and citizen science projects, which have been shown to provide learning benefits and foster a sense of agency among participants. Designing these activities to cater to diverse backgrounds can enhance environmental science learning for young people. In higher education, e-learning tools have been used to promote sustainability literacy, with synchronous sessions improving theoretical knowledge and asynchronous activities developing intercultural communication and e-learning skills. Incorporating ecosystem services into STEM education, as demonstrated in an online soil science course, connects theoretical knowledge with real-world applications, enhancing student engagement and understanding

2. Student Engagement and Learning Effectiveness in Online Education

The integration of personalized learning approaches significantly impacts student engagement and learning outcomes. Research demonstrates that tailoring learning paths and materials to individual student preferences enhances the overall educational experience, with students engaged in personalized, self-regulated online learning exhibiting higher post-test scores and greater learning gains compared to conventional settings. Further exploration into motivational factors influencing student engagement highlights the critical role of personalized and interactive content. Task that supports student independence, social communication, personal engagement and real-world usefulness tend to increase motivation, while those that are too hard, cause self-doubt, or create mental stress often lead to lower motivation. This suggests that to maintain high levels of engagement, online educational content must be designed to be motivating and accessible, especially during emergency situations. Additionally, immersive game environments significantly promote creative thinking and personal learning motivation, indicating that integrating gamified elements into online education can further enhance student engagement

Table 3. Student Engagement and Learning Effectiveness in Online Education

No	Author Name and Year	Objectives	Methodologies	Findings	Conclusion and Future Research
1	Ye J.-H., Lee Y.-S., He Z. (2022)	To determine whether students' learning expectations meet the qualities of distance learning and to explore how expectation beliefs are connected with satisfaction in	Snowball sampling method; Expectation confirmation theory and its model	(1) Expectancy value belief positively related to theoretical course satisfaction but negatively to practical course satisfaction; (2) Student satisfaction with both theory and practical parts of the course showed a positive link with how well they learned; also, better	Suggested improving course quality, reducing disturbances to enhance students' expectations, learning effectiveness, and continuous learning intention.

		the course, learning success and the intention to continue learning		learning led to stronger intention to continue studying	
2	Ismailov M., Ono Y. (2021)	This study aims to identify what elements effect the motivation of first-year university students in Japan when they do online assignments during the COVID-19 time.	Qualitative study; post-course survey; Inductive content analysis	Students feel more motivated when the assignments help them to be more independent, interact with other, follow their interest, and have real-life use. But when the tasks are too hard, they feel not capable, or the mind gets too full, their motivation becomes low.	It is suggested to make learning materials and tasks more motivating especially in time of emergency situations. Future research should focus on psychological, cognitive, social, and environmental learning conditions.
3	Lau K.W. (2023)	To encourage students to create new games and support their learning in more creative way through immersive game environments.	Self-regulated Learning model; Factor analysis; Three situated immersive games	Positive results show that deep involvement in games can help students think more creatively, feel more motivated to learn and be more aware of their surroundings.	Suggested using situated learning pedagogy for discovery learning and refining future curricula with immersive games. Future research could explore further applications of game-based learning environments.
4	Tuckel P., Pok-Carabalona K. (2023)	To understand how students feel about distance learning by looking at four things: problems with technology and learning environment, their choice between learning at the same time or different time, their liking gor online of face-to-face classes, and what they prefer for future online learning	Two anonymous online surveys	Significant issues with unreliable internet and poor home learning environments; narrow preference for asynchronous learning; general preference for in-person courses, especially for concentration, motivation, and social interaction. Majority inclined to take more online courses in future.	Highlighted need to address technological and environmental challenges. Suggested future research on improving online learning environments and exploring factors influencing student preferences for different modalities.
5	Wangid M.N., Putra C.A., Rudyanto H.E. (2021)	To examine the impact of science-math stories based on digital learning on elementary	Pretest-post-test control group design with more than one experimental group	Science-math stories based on digital learning improved problem-solving skills. Realistic fiction with	Recommended using digital literacy media to enhance problem-solving abilities. Future research could expand on different

		students' problem-solving skills.		environmental problem-solving themes was effective.	types of digital content and their impact on various learning outcomes.
6	Zou Y., Shen L., Dadparvar S. (2022)	To analyse the influence of e-leaning behaviour in students learning performance of disaster emergency knowledge	Deconstruction program behaviour theory; Task technology fit model; PLS (partial least squares) regression analysis	High reliability and validity of measurement indexes. Information literacy, technical characteristics, and facilitation conditions positively influenced learning performance.	Provided practical suggestions for improving e-learning environments. Future research could focus on further analysis of e-learning behaviours and their impacts on different knowledge areas.

3. Innovative Approaches and Challenges in Distance Learning

The integration of personalized learning approaches in distance education represents a significant innovation aimed at enhancing student autonomy and learning outcomes. The study by Ingkavara et al. (2022) highlights how personalized learning environments can support self-regulated learning, particularly in subjects like Physics. Observational learning is another promising strategy in the realm of distance education. Doublet et al. (2022) investigated the potential of social learning through observation in a spatial task among rats, showing that rats could learn a reward location solely by observing a conspecific. This finding is applicable to human learning, suggesting that observational learning can be leveraged in distance education to facilitate understanding and retention of complex concepts. By integrating social learning elements, such as peer demonstrations and collaborative projects, distance learning platforms can mimic the benefits of in-person interactions, fostering a more engaging and effective learning environment Doublet et al. (2022). Despite these innovations, significant challenges persist in distance learning, particularly in managing physical education (PE) and practical skills training. During the COVID-19 pandemic, Fazleeva et al. (2021) examined how distance learning affected PE classes at Kazan Federal University. The use of mobile devices as educational tools also presents both opportunities and barriers in distance learning. Nikpeyma et al. (2021) conducted a qualitative study among nursing students to identify these factors. While mobile devices facilitate easy access to information and flexible learning, challenges such as limited internet access, varying levels of information literacy, and cultural-environmental barriers hinder their effective use.

Moreover, the implementation of a digital self-contained module for accounting students, aimed at assisting in writing tasks related to the evaluation of financial, social, and environmental performance, illustrates the blending of traditional and digital teaching methods Everaert & Safari (2021). This innovative web-based module provides a structured approach to learning, offering step-by-step guidance and self-explanatory tips. The positive feedback from students regarding the module's usability and the achievement of learning outcomes indicates its efficacy in enhancing students' competency in real-world settings. The challenges of distance learning are also evident in the context of knowledge retention in higher education institutions Enakrire & Smuts (2023). The exploration of unsupervised online learning for robotic interestingness with visual memory showcases the intersection of artificial intelligence and distance learning Fan et al. (2022). In the realm of environmental education, the shift to online programs during the COVID-19 pandemic has necessitated a systematic review of program characteristics that promote environmental literacy Merritt et al. (2022) examined how policy constraints could be utilized to regulate uncertainty in offline RL, reducing the need for large computational ensembles. By integrating behavioral cloning into policy updates, their study demonstrated that it is possible to achieve robust policy learning with lower computational costs. Applying this approach in distance learning can lead to more efficient and scalable educational technologies, capable of delivering high-quality learning experiences without overwhelming system resources Merritt et al. (2022).

The integration of personalized learning approaches in distance education represents a significant innovation aimed at enhancing student autonomy and learning outcomes. A study on personalized learning environments in Physics demonstrated that students engaged in personalized, self-regulated online learning exhibited higher post-test scores and greater learning gains compared to conventional settings. This underscores the importance of adaptive learning systems tailored to individual needs, enhancing overall educational efficacy. Another innovative approach is the application of continuous reinforcement learning (CRL) to dynamically adapt educational content, as evidenced by its effective use in robot motion optimization. This approach suggests that educational systems can improve responsiveness and engagement by continuously updating learning pathways based on student performance. Observational learning is also promising, with research showing that social learning through observation can facilitate understanding and retention of complex concepts. Integrating social learning elements, such as peer demonstrations, can mimic the benefits of in-person interactions in distance learning.Despite these innovations, significant challenges persist, particularly in managing physical education (PE) and practical skills

Conclusion

In conclusion, the findings highlight the transformative potential of well-structured e-learning models in enhancing environmental education. Overcoming challenges such as technological limitations and creating contextually relevant content is crucial for sustaining student engagement and improving learning outcomes in online environments. Furthermore, addressing the balance between policy limitations and computational demands in offline reinforcement learning can enhance the efficiency and scalability of educational technologies. Ultimately, these innovative strategies and challenges emphasize the importance of adopting adaptive and flexible educational approaches to optimize learning outcomes in the digital era.

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