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The Role of Interactive Technologies in Climate Change Education

Laxmi Yadav
Professor,
Department of Zoology,
Rajkiya Mahila Mahavidyalaya, Aurai, Bhadohi, U.P.

Abstract

Climate change is one of the most pressing issues of today and the education system requires new solutions to equip students with knowledge, skills and attitudes to take action in an ecologically sustainable way. The issue of Climate Change is so complex and has so many real-world implications that it is hard to "pass" on to students using the traditional tools. This may lead to a need for more engaging and experiential learning environments. Interactive technologies, such as virtual reality (VR), augmented reality (AR), gamification, artificial intelligence (AI), simulations, mobile learning apps, and digital collaboration platforms provide new ways to deepen the learning experience related to climate change and encourage active learning, critical thinking, and problem solving. This study examines the impact of interactive technologies on the capacity of students to learn about the climate and their awareness and desire to act in a sustainable manner. The method of research used was quantitative method, which consisted of primary data obtained from the learners through making a structured questionnaire. The results show that technology-enhanced learning experiences have a significant impact on an increased engagement, conceptual understanding and motivation of the learners to engage in climate-friendly practices. The digital, interactive tools also promote collaboration, hands-on learning, and making good decisions, as students can gain a deeper understanding of climate scenarios and make informed decisions about the environment. Yet barriers like access to digital infrastructure, preparedness of teachers, financial pressures, and digital literacy still impact the effective implementation of these technologies across learning environments. Overall, the study suggests that interactive technologies hold great promise for revolutionizing climate change education by offering a more immersive, accessible, and action-oriented learning experience. Creating digital infrastructures, conducting regular teacher training and integrating environmental education in a technology-based way into the curriculum can enhance the education of environmentally responsible citizens for long-term sustainability. The results offer actionable guidance for educators, policymakers, curriculum designers, and educational institutions aiming to promote digital innovation for supporting climate education and sustainable development.

Keywords: Climate change education, interactive technologies, climate literacy, environmental education, digital learning, virtual reality, augmented reality, gamification, sustainability, experiential learning.

Introduction

Climate change is one of the greatest problems facing the world in the twenty-first century, impacting ecosystem, economy, public health and social wellbeing. The recent global warming, extreme weather events, biodiversity loss, sea-level rise, and environmental degradation have made it clear that it is important for citizens to be informed and involved in climate mitigation and adaptation. Despite the rollout of climate policies and sustainability actions by governments, industries and international organizations, education is still one of the key drivers to build up knowledge, skills, attitudes and behaviours needed to tackle environmental challenges. Climate change education empowers students with the knowledge and tools to understand the science of climate change and to think and act critically in order to help create a sustainable future. Although traditional teaching and learning methods have been important in

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spreading environmental knowledge, they typically involve passive learning that may not be sufficient to enable learners to gain knowledge about the complexity and interconnectedness of climate systems. Climate change is a dynamic scientific process, uncertain future scenarios, and multidisciplinary perspectives that call for learners to interpret data, analyze the interactions of the environment, and assess sustainable solutions. Interactive technologies in education can provide an opportunity to create more dynamic and student-centred learning environments that will promote environmental literacy and give students meaningful opportunities to participate, while facilitating the shift to digital learning. Interactive technologies, such as virtual reality (VR), augmented reality (AR), artificial intelligence (AI), simulation software, educational games, mobile learning applications, digital storytelling, geographic information systems (GIS) and online collaborative platforms are changing the way EE is provided. The technologies allow students to visualize the processes of climate, explore virtual ecosystems, conduct virtual experiments, analyze environmental data and collaboratively solve problems. Interactive technologies foster active learning and hands-on experience, enabling students to relate classroom ideas to the realities of the environment and enhance their retention and understanding. Interactive technologies also enable personalised and inclusive learning, allowing for flexibility in access to learning and adopting a flexible approach to learning style. Technology such as individualized feedback using adaptive learning systems and gamification of learning using challenges, rewards and interactive learning tasks can enhance the motivation of learners. Virtual field trips and simulations help students learn about climate change impacts in geographical locations beyond their reach, bridging the geographical divide.Climate change effects in different geographical locations can be experienced by the students without geographical limitations with virtual field trips and immersive simulations. Moreover, the use of a digital platform for collaboration promotes dialogue, the exchange of knowledge and collective action between learners from various cultural and geographical backgrounds, thereby promoting international awareness of climate responsibility. The use of technology-based climate education in school curriculum, university education, and community engagement has become a growing trend in education globally. There are various global instruments that highlight the need to equip people with the capabilities to foster sustainable development and environmental care, including the United Nations Sustainable Development Goals 4 (Quality Education) and 13 (Climate Action). The development of digital infrastructure has also increased the potential to incorporate innovative instructional technologies into climate education, providing teachers with the ability to present content in an interactive way and foster inquiry, reflection and evidence-based decision making. Although these developments have emerged, interactive technologies are still not fully realized in the field of climate change education due to a number of factors. Accessibility of digital infrastructure, differences in technological literacy, limited institutional resources, insufficient teacher training, and the fact that different gaps between urban and rural educational contexts can limit the use of technology enhanced learning. However, the scientific correctness, pedagogical effectiveness and cultural appropriateness of digital learning tools still remain crucial for the educational impact to be made. In this context, the present study aims to analyze the contribution of interactive technologies to the improvement of climate change education, through the analysis of their effects on learning motivations, environmental awareness, knowledge retention, critical thinking and sustainable behavioral intentions. Technology-supported educational approaches have a potential influence on climate literacy which can help teachers, policymakers, curriculum designers and educational institutions to create new and innovative climate literacy learning approaches that will foster meaningful engagement in climate action. The results will be added to literature related to digital learning and the education of sustainability and will offer practical knowledge for the application of interactive technologies in modern climate change education.

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Background of the study

Climate change is one of the greatest challenges of our time that impacts ecology, economy, public health and social well-being. The importance of effective climate literacy among learners of all ages has been highlighted by the effects of global warming, biodiversity loss, extreme weather phenomena and environmental degradation. Education is a key driver in providing knowledge, skills, values and attitudes to be able to understand climate science, assess environmental issues and engage in sustainable decision-making. But the traditional method of instruction usually focuses on lectures and textbook learning, thereby hardly involving the students or developing their practical ability in solving climate-related problems. As the complexities and inter-disciplinariness of climate change issues are becoming more pressing, education strategies for active participation, critical thinking and experiential learning are necessary. The application of educational technology has transformed the climate change educational landscape, offering new opportunities to engage with the knowledge of climate change in an interactive and digital format. A new educational technology has emerged, opening up new potential for a transformation of the climate change education. There are technologies that allow students to view the processes of the environment in virtual reality (VR) or augmented reality (AR), explore real life scenarios and feel the impact of climate change decisions in an immersive manner, such as gamified learning platforms, simulations, interactive multimedia, digital storytelling, or artificial intelligence, and online collaborative environments.

These technologies promote inquiry based learning, enhance engagement with the learner, and help to connect theories to real-world environmental situations. Interactive technologies also facilitate personalized learning, immediate feedback, collaborative problem-solving, and access to up-to-date climate information, making climate education more relevant and meaningful.

Digital technologies are becoming more and more embedded in education systems, and international efforts to integrate education for sustainable development have brought a growing interest in technology-enhanced climate learning. The use of digital tools is becoming widespread in the education sector to promote students' awareness of the environment and promote sustainable actions. Despite these advances, the impact of these disparities in the effectiveness of interactive climate education, especially in different educational and socio-economic contexts, remains a factor. In addition, in many areas there is a lack of empirical evidence on the long-term effects of interactive technologies on climate knowledge, environmental attitudes and pro-environmental behaviour.

Given the above context, the current study explores interactive technologies as a tool for improving climate change education. It aims to gain insight into the impact of technology-based learning environments on the climate competence, motivation and attitude of learners and to explore the opportunities and obstacles of their application. The results will be beneficial to teachers, curriculum developers, policy makers, and educational institutions interested in implementing innovative and learner-centered technological methods to boost climate education.

Objectives of the Study

1. To investigate the effects of interactive technologies on the improvement of education on climate change to students.
2. To evaluate the effectiveness of digital learning tools, simulations, virtual reality and gamification to enhance students' understanding of concepts related to climate change.
3. To assess the impact of interactive technologies on learner environmental awareness, attitudes and sustainable behaviors.
4. To find out what influences interactive technology use and implementation in climate change education.
5. To examine the correlation between the interactive technologies use and students' climate change learning engagement.

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Literature Review

Climate change education (CCE) has become an important part of sustainable development and is defined by a goal to increase the climate literacy, environmental responsibility and pro-environmental behaviour of people by using innovative pedagogical approaches. Comprehensiveness and timeliness of key climate related issues present a challenge in traditional lectures and researchers suggest interactive technologies that can make students actively involved in scientific inquiry and decision making. Existing systematic reviews find that the effect of using technology was equivalent or greater than conventional approaches in enhancing the knowledge, attitudes, and behavioral intentions of learners regarding climate education.

The systematic review by Monroe et al. (2019) identified effective practices in the teaching of climate change, which include the following: active learning, real-world contexts, collaborative learning, interaction with scientists, and project-based learning. The authors stated that the interactive technology is crucial in climate education because learning experiences that are more than just information delivery lead to increased understanding of climate.

Bhattacharya et al. (2021) conducted a systematic review of empirical research on K–16 climate education and found significant increase in the use of technology to support learning environments. They concluded that digital simulation, visualization, online learning platforms and teaching models based on inquiries are tools that support the understanding of the climate systems, and promote scientific reasoning and environmental awareness among students. They also highlighted the need to incorporate technology into inquiry-based pedagogy and not as an independent pedagogy.

The research conducted by Wu and Lee (2015) pointed out that digital games have educational potential in climate education. The authors showed, however, that climate games could provide immersive environments to explore various mitigation and adaptation options, consider policy options, and witness long-term environmental impacts of their choices. These types of interactive sessions are more motivating, engaging and facilitates systems thinking and a better understanding of complex interactions in the environment.

Digital simulations are one of the most popular interactive technologies adopted in EE. Tofel-Grehl et al. (2025) state that simulation software offers students opportunities to experiment with environment variables, explore climate scenarios and engage in real science investigation experiences. They conducted a scoping review and found that simulations, virtual reality, sensor-based learning, remote sensing technologies, digital modeling, web-based learning, and educational games were the most prevalent technological strategies adopted for teaching about climate change today. The review also highlighted the need for technological tools to be integrated with data literacy and science reasoning activities.

Virtual Reality (VR) and Augmented Reality (AR) have been gaining in popularity due to their potential for creating immersive environments. Hadi and Kurniawan (2025) conducted a review of interactive educational games that integrate AR, simulations, and storytelling techniques and found that AR, simulations, and story-based learning can have a positive impact on learners' awareness of climate risks and mitigation measures. After reviewing, they concluded that the immersive technologies have a positive effect on emotional engagement, knowledge retention, and behavioral intentions related to environmental conservation.

Gamification is also one of the effective methods that is being used in climate education. Interative games require students to face environmental challenges, utilize natural resources and feel the effects of climate-related choices in simulated environments. In such learning-through-games environments, critical thinking, cooperation and problem-solving abilities are reinforced and high levels of motivation and involvement are maintained.

The use of online collaborative platforms to enhance climate learning outside the classroom is the focus of recent literature. Participation in collaborative climate action projects allows geographical learners to exchange ideas, analyse environmental data and engage with a learning

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environment via web-based discussion forums, collaborative mapping tools, citizen science platforms and cloud-based learning environments. These technologies enable the sharing of knowledge all over the world and promote collective responsibility for environmental sustainability.

Interactive technologies also facilitate data-informed learning by allowing students to analyze real climate data from satellites, weather stations and environmental sensors. Learners use visualization dashboards, Geographic Information Systems (GIS) and remote sensing applications to build analytical skills and to gain insights into spatial and temporal climate change patterns. The authentic learning experiences enhance scientific literacy and evidence-based decision making.

Some new direction is the incorporation of IoT (Internet of Things) learning equipment in EE. Students can use IoT sensors to keep track of the environmental parameters like air quality, temperature, soil moisture, and carbon emissions in real time. Experiential learning activities around environmental monitoring promote active learning and make connections between classroom learning and problems in the local environment.

Additional evidence indicates that climate change education interventions work, through the use of meta-analysis. Our literature review by Aeschbach et al. (2025) integrated results from several empirical climate education studies, and concluded that there are robust positive impacts on climate knowledge, environmental attitudes, and behavioral intentions. Their results indicate that the technology-supported instructional methods yield moderate to large gains in learning outcomes when compared to traditional instruction.

Despite the growing awareness of climate issues, many education systems still struggle to attain a satisfactory level of climate literacy, as noted by Ramos and Rodrigues (2024). They placed great emphasis on innovative pedagogical models and approaches, including STEAM education, interactive learning technologies, and interdisciplinary instructional approaches, to help prepare learners for climate adaptation and mitigation.

While significant development work has taken place in the creation of interactive Climate education tools, there are a number of research gaps. Previous research tends to focus on specific technologies like games or simulations, or even virtual reality alone, with few studies exploring a cohesive digital ecosystem involving multiple technologies in a formal education environment. In addition, evidence from developing countries is still limited and a need for further empirical studies on the effectiveness of interactive technology in different educational environments exists.

The literature shows that interactive technologies such as virtual reality, augmented reality, simulations, educational games, Internet of Things (IoT) tools, geographic information systems (GIS) applications, collaborative online platforms, and digital visualization tools have highly positive effects on the enhancement of climate literacy, learner engagement, scientific reasoning, and pro-environmental behavior. The present findings offers solid theoretical and empirical basis to explore the effectiveness of interactive technologies in the reinforcement of climate change education and sustainable environmental actions.

Material and Methodology

A quantitative, cross-sectional research design was used to investigate the effectiveness of interactive technologies to improve climate change education to higher education students. The research employed only primary data that were gathered through a structured questionnaire, adapted from previous research constructs in EE, ET and EE learner engagement. The questionnaire was structured into two parts - demographic information (age, gender, subject studied, level of study) and a second that had items that measured perceptions of interactive technologies, students' engagement, knowledge of climate change, awareness of environment and behavioural intentions on a five-point Likert Scale ranging from 1 (Strongly Disagree) to 5 (Strongly Agree). The instrument was reviewed by experts in education and environmental

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studies and pilot tested to ensure clarity, reliability and content validity before the main survey. The target population were students from undergraduate and postgraduate courses in universities and colleges where digital learning platforms are included in the curriculum. Simple random sampling method was used in selection of the respondents, with a view of students with various academic disciplines taking part in the study. Approval of the participants was obtained and the data was collected online and offline using both survey methods. The ethical issues such as voluntary participation, anonymity, confidentiality and the right to discontinue at any point during the research process were carefully adhered to. The independent variable of the study was the interactive technologies, such as digital simulations, virtual reality programs, educational games, augmented reality, interactive mobile applications, multimedia learning platforms, and internet-based collaborative learning environments for climate change education. Climate change education effectiveness was measured on the basis of the following indicators: conceptual understanding of the climate science, environmental awareness, critical thinking, learning engagement, problem solving, willingness to adopt sustainable environmental practices. Coded and analyzed using IBM SPSS Statistics. Descriptive statistics such as frequencies, percentages, means and standard deviations were employed for summarising the characteristics of the respondents and the important study variables. Cronbach's alpha coefficient was used for testing reliability of the measurement scales and expert review and pilot testing were used for testing the construct validity. Pearson's correlation analysis was used to explore the correlation between interactive technologies and effectiveness of education about climate change. Moreover, simple linear regression was performed to find out the prediction of interactive technology for outcomes of climate change education. The significance of the results was judged at the 5% level ($p < .05$), which guaranteed the reliability and strength of the results. This methodological approach provides a structure for understanding the contribution of interactive digital technologies to the enhancement of students' knowledge, engagement and pro-environments attitudes towards climate change.

Results and Discussion

Results:

The teachers and students of higher education (412 valid answers) were asked about the effectiveness of interactive technologies in climate change education and the answers were analyzed. The interactive technologies that the authors found included virtual simulations, gamified learning platforms, augmented reality (AR) and virtual reality (VR), digital storytelling, interactive videos and learning management systems (LMS). Four major constructs were explored: Interactive Technology Usage (ITU), Student Engagement (SE), Climate Change Knowledge (CCK) and Environmental Action Intention (EAI). Descriptive statistics, Pearson correlation and simple linear regression were used to analyze the data. The results show that the use of interactive technologies significantly positively influences the engagement, acquisition of knowledge and willingness to engage in environmentally responsible behaviors of the students.

Table 1: Descriptive Statistics of Study Variables (N = 412)

Variable	Mean	Standard Deviation
Interactive Technology Usage	4.18	0.59
Student Engagement	4.11	0.63
Climate Change Knowledge	4.06	0.61
Environmental Action Intention	4.02	0.66

Source: Primary Data

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Interpretation

All of the descriptive statistics have high scores (over 4.00), suggesting that on the whole, respondents believe interactive technologies are effective learning tools in a climate change education program. The mean score (M = 4.18) for Interactive Technology Usage was the highest, showing that digital learning platforms were broadly accepted. Student Engagement and Climate Change Knowledge also showed good average scores, suggesting that interactive learning environments foster the engagement and enhance conceptual understanding of climate related issues.

Table 2: Correlation Analysis

Variables	ITU	SE	CCK	EAI
Interactive Technology Usage (ITU)	1.000			
Student Engagement (SE)	0.731**	1.000		
Climate Change Knowledge (CCK)	0.694**	0.716**	1.000	
Environmental Action Intention (EAI)	0.668**	0.689**	0.742**	1.000

Note: p < 0.01

Source: Primary Data.

Interpretation

The correlation analysis results show that all the studied variables are significantly correlated with each other. Student Engagement is significantly and positively correlated with Interactive Technology Usage (r = 0.731), Climate Change Knowledge (r = 0.694) and Environmental Action Intention (r = 0.668). Moreover, Environmental Action Intention is found to be the most correlated with Climate Change Knowledge (r = 0.742), implying that high level of knowledge gained from the interactive technologies makes learners to have more environmental responsible behaviors.

Table 3: Simple Linear Regression Analysis

Dependent Variable: Climate Change Knowledge

Model	B	Standard Error	Beta	t-value	Sig.
Constant	1.247	0.188	—	6.63	0.000
Interactive Technology Usage	0.673	0.041	0.694	16.41	0.000

Model Summary

R	R^2	Adjusted R^2	F	Sig.
0.694	0.482	0.481	269.31	0.000

Source: Primary Data.

Interpretation

The regression analysis shows that Interactive Technology Usage significantly predicted Climate Change Knowledge ($\beta = 0.694$, $p < 0.001$). The model accounts for 48.2% of the variation in climate change knowledge ($R^2 = 0.482$). The small p-value of the F-test verifies the overall significance of the regression. The results indicated that the use of interactive technology has a significant positive effect on improving learners' knowledge of climate change concepts.

Discussion:

The results show that the use of interactive technologies is an important tool for the reinforcement of climate change education. The ones that utilized higher levels of technology

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were more engaged, gained a better understanding of the concept, and had higher intentions to take responsible action towards the environment. Interactive learning tools that provide experiential learning opportunities to the learners to help them see complex climate systems and environmental issues more clearly than traditional learning tools, such as simulations, virtual laboratories, learning games, and immersive AR/VR experience.

There is a positive correlation between student engagement and climate change knowledge, suggesting that interactive technologies stimulate active learning, collaboration and critical thinking. A combination of the technology and active involvement by the learners allows them to retain scientific concepts and apply these ideas to their surrounding environmental issues. The results are in line with the constructivist learning theory that highlights the participation of learners and building knowledge by providing meaningful experiences.

Results of the regression analysis also show that interactive technology usage is one of the significant predictors in the regression model and accounts for almost half of the variation in the learning outcomes of climate change. This underscores the need for digital pedagogies as an integral part of EE programmes. Using interactive technologies in institutions can enable personalization, real-time feedback, and group problem-solving, enhancing the effectiveness of education.

Furthermore, there are close relationships between the knowledge of climate change and the intention to take action on the environment, indicating that an increase in climate change knowledge is accompanied by an increase in the intention to act on the environment such as conserving energy, preventing waste, protecting biodiversity, and participating in climate-change mitigation actions. The results highlight the potential for climate education through technology to enhance not only student achievement but also environmental responsibility.

The aggregated findings highlight the increasing focus on digital innovation in education and illustrate how interactive technologies are a promising pedagogical approach to building climate literacy, engagement, and sustainable behavioural intentions. As a result, continued investment in interactive digital infrastructure, teacher training and technology-supported climate education are needed in educational institutions and policy makers to support learners in preparing them for challenges of the present and future in the context of climate change.

Conclusion

Climate change education is now key to empowering learners to confront one of the greatest challenges of the 21st century. The introduction of interactive technologies into the school has led to the development of a new approach to learning climate-related concepts, which is more engaging, experiential and learner-centred. Virtual reality, augmented reality, simulations, gamified learning platforms, mobile apps, geographic information systems (GIS) and artificial intelligence-supported learning environments allow students to investigate intricate environmental processes in real-world scenarios and interactive environments. These strategies promote more conceptual understanding, problem solving, critical thinking and decision making regarding climate issues. This study suggests that interactive technologies are effective to raise awareness, motivation and involvement of learners in climate change education and help them to build environmental responsibility and sustainable behavior. Digital learning materials also promote collaboration, enquiry-based learning and the practical use of scientific knowledge, which allows the learner to relate what they learn in the classroom to environmental issues in the local and global environments. The effective use of technology in climate education, however, requires sufficient digital infrastructure, preparedness of teachers, curriculum assimilation, availability of technological resources and ongoing institutional support. These challenges must be overcome to harness the full educational potential of interactive technologies. Finally, interactive technologies offer innovative solutions to improve climate change education by offering meaningful, accessible, engaging learning experiences. Digital pedagogies are becoming more and more common in educational institutions, and the

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technologies can be crucial in providing the knowledge, skills, attitudes, and resilience needed to prepare the next generation for adaptation and mitigation to climate change. Educational technology, teacher professional development, interdisciplinary curriculum development, and the integration of evidence-based pedagogies into the classroom will continue to be vital to the success of the effective teaching and learning of climate change and to the larger objectives of global climate action and environmental sustainability.

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