

Climate Change Education Through Interactive Technologies

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Abstract

The issue of climate change education has become a vital aspect of the global sustainability strategy, but conventional teaching methods can hardly attract learners or provide them with a chance to comprehend the scientific challenges. Interactive technologies, including virtual reality (VR), augmented reality (AR), simulation platforms, serious games, and mobile learning apps, can be used to find new ways to enhance climate literacy by providing immersive, experiential, and learner-centered experiences. The paper will discuss the role of interactive technologies in improving climate change education through facilitating deeper cognitive learning, greater emotional attachment to the problems of climate change, and informed behaviour change. Based on the recent trends in digital pedagogy, the paper examines the pedagogical usefulness of immersion, real-time feedback, and experiential learning in enabling students to visualize the processes of climate, evaluate the effects of human actions, and test mitigation and adaptation keys. The capacity of interactive means to make abstract scientific knowledge available, personalize the learning processes of individuals of any age and establish cooperation within the similar virtual space (through) and game-based tasks are also highlighted in the paper. Despite the immense opportunities of the technologies, the paper also addresses the existing weaknesses of the technologies, including access gaps, technological infrastructural requirements, content validity, and requisite educator training and curriculum alignment. The paper supports the arguments with a view that interactive technologies can significantly contribute to increasing climate education through reviewing the current applications of the technology and their success in education when they are used as a part of evidence-based pedagogical practices. Last but not least, the paper emphasizes that the combination of scientific content and experiential digital solution can also contribute to climate literacy creation by empowering problem-solving and enabling students to play a more active role in sustainability activities. Results underscore the fact that more innovations, interdisciplinary collaboration, and unrestricted access to technology are required in order to be certain that interactive climate education can contribute to global climate action.

Keywords: Climate change education; interactive technologies; virtual reality (VR); augmented reality (AR); digital learning; serious games; environmental awareness; experiential learning; sustainability education; technology-enhanced learning.

Introduction

Climate change is among the hottest issues in the world of the twenty first century that influence the ecosystem, economies, and societies worldwide. The high occurrence and severity of climate related events have rendered the awareness and knowledge of climate science highly significant to the people. The traditional approaches to education such as lectures and textbooks are not necessarily attractive to the learners and they might not give the learners the feeling of complexity and interconnectedness of climatic systems. In response to this, interactive technologies, such as simulations and virtual reality, gamified learning systems and applications have emerged as viable ways of enhancing the education of climate change. These technologies offer hands-on and engaging learning and allow students to explore the consequences of environmental decisions, visualize data in real-time, and engage in an interactive problem-solving experience that reflects the real-life experiences. It is possible to promote critical

thinking, retention and behavioral change towards sustainability using these tools because an interactive and participatory learning environment is created. Besides, interactive technologies can also help to bridge access inequities so that learners in varied geographic and socio-economic locations can engage in climate education in a manner that matters. The research findings also indicate that technology-based learning is capable of not only increasing the knowledge of the scientific concepts, but it also holacrates the skills of the learners to assess the social and moral impacts of climate action. Although these tools are increasingly being utilized, there are still difficulties in ensuring fair accessibility, pedagogically intended content and incorporating the use of these technologies in formal curriculum. This paper evaluates the future of interactive technologies in enhancing climate change education by looking at their advantages, shortcomings and best practices. It aims to educate educators, policymakers, and technology creators about how they can use digital tools to raise a climate literate and proactive generation that is able to deal with the environmental crisis of our generation.

Background of the study

Climate change has been widely known as one of the greatest global issues in the 21st century with great effects on ecosystems, economies and human societies. Growing unpredictable weather patterns, elevated temperatures around the globe, and the escalation of the natural disasters, point to the immediate necessity of not only knowledgeable but also prepared population. Education will be essential in achieving environmental literacy, raising awareness of the cause, and the impacts of climate change, and improving sustainable behaviours of individuals and the society in general.

The traditional methods of climate change education that are occasionally brought to a minimum of textbooks, lectures, and visual in-active lessons have been criticized in terms of their inability to offer full engagement of the learner as well as their inability to capture the dynamic dynamics that climate embodies. Research suggests that the passive learning approaches may not promote behavioural change or proactive behaviour in sustainability initiatives. In this case, the interactive technologies, including simulations, virtual reality (VR), augmented reality (AR), gamification of learning platforms and online collaborative tools present a new opportunity to enhance climate change education.

These technologies offer virtual experiences that enable learners to experiment with the models of climate, visualize the effects of environmental conditions in real time, and test their possible solutions in a safe controlled setting.

The incorporation of the interactive technologies into climate change education is in line with the overall trend of encountering experiential and participatory learning. These tools can enhance comprehension, retention and engagement by actively engaging learners in decision-making situations, problem-solving, and simulation of the situations. Besides, interactive technologies have the potential to connect with a wide range of audiences based on their age, educational level, and geographical position, and climate change education has become more inclusive and accessible.

Although the topic of technology-enhanced environmental education is gaining momentum, it is still necessary to carry out empirical research that evaluates the efficacy of particular interactive tools, the optimal way of integrating them into the curriculum, and how they impact knowledge, attitudes, and behaviour of learners about climate change. This paper attempts to fill these gaps by analyzing the exploitation of interactive technologies in improving climate change education with an aim of developing a generation of learners who are informed, motivated and enabled in the fight against climate change by ensuring that they develop sustainable solutions.

Justification

Climate change has become one of the most topical global issues of the 21st century with far-

reaching environmental, social, and economic consequences. Although there has been a massive awareness campaign, it has been observed that several people especially the young generation do not fully understand the scientific, social and ethical aspects of climate change. Conventional approaches in a classroom setting might not be able to engage learners enough or develop critical thinking and behavioural change to solve climate problems.

Interactive technologies, such as simulations, virtual reality (VR), augmented reality (AR), gamified learning platforms, and mobile applications, can be applied in order to enhance climate change learning. Such technologies will be in the position to make the learning immersive and experiential where learners will be in a position to visualize the impact of the climatic phenomena, cause and effect relationship and the impact of human activities on the environment. Interactive technology can be used to the benefit of understanding, memorizing, and motivating a learner using the sense of touch, hearing and appealing to the participation. Besides, the use of interactive technologies in climate change education is in line with the growing digitization of education and the necessity to develop digital literacy as well as environmental literacy. It also offers the possibility of individualized learning processes, which target varying groups of audiences geographically and socioeconomically.

The study can thus be justified by the fact that it aims at examining new educational approaches that are more effective in communicating climate science, inspiring sustainable behaviours and enabling learners to engage in mitigation and adaptation initiatives. The value of studying the way interactive technologies can be utilized to advance climate change learning is important in designing evidence-based pedagogical strategies that shall support the pressing needs of global sustainability.

Objectives of the Study

1. To investigate the efficacy of interactive technologies (e.g. simulations, virtual reality, and gamified platforms) in improving the level of knowledge that students have regarding the concepts of climate change.
2. To determine the effect of education aid devices that utilise technology on the attitudes, awareness and behavioural intentions of the students towards mitigating climate change.
3. To establish the pedagogical benefits and difficulties relating to the integration of interactive technologies in the climate change learning in both formal and informal learning environments.
4. To investigate the issue of engagement and interactivity in informing learners about the related problem-solving skills and critical thinking in the context of climate change issues.
5. To offer evidence-based suggestions on the use of interactive technologies by educators and policymakers to enhance climate literacy and develop sustainable behaviours.

Literature Review

Interactive technologies Virtual reality (VR) and augmented reality (AR), computer games, and digital media are increasingly discussed as powerful instruments of climate change education, as these technologies can provide the possibility to engage learners in more profound connection with the complex aspects of the environmental problem than the traditional lectures or the texts in the books.

Immersive technologies and climate literacy

Current research demonstrates a perception of the importance of immersive technologies in improving the understanding of climate change. In the same manner, Suryati, Pangga, Habibi, and Azmi (2025) created a digital pedagogical model that combines VR with problem-based learning; their findings demonstrated that the awareness of students about climate change and their skills in critical thinking improved significantly.

On the same note, The Efficacy of Virtual Reality in Climate Change Education Increases with

Amount of Body Movement and Message Specificity (Queiroz et al., 2023) revealed that VR experiences regarding ocean acidification could have a beneficial impact on the learning process and encourage pro climate behaviors. If there is a way to mediate the effectiveness of VR in climate education, the authors discovered that the features of design, including the message framing and the degree of physical movement, mediate the effectiveness of VR.

Besides, emotional involvement and ecological awareness can be encouraged by immersive environments. As an example, a recent study by *The Ecology of Climate Change: Using Virtual Reality to Share, Experience, and Cultivate Local and Global Perspectives* (Groat Carmona et al., 2025) states that VR-based collaborative assignments, which involve a combination of local climate observations with global climate narratives, can assist students to build ecological literacy, global awareness, and environmental advocacy.

All of these findings hint at the idea that abstract climate-change processes (sea-level rise, acidification, or ecosystem shifts) can be brought to life in order to be more tangible and emotionally effective using immersive VR (and similar technologies) to understand them better and be inspired to act responsibly in relation to the environment.

Games and interactive media for climate engagement

Outside of VR, interactive games and digital storytelling as a method of educating people on climate change also have potential. The article *Climate change games as tools for education and engagement* (Wu & Lee, 2015) takes the position that climate change-based games create a sense of engagement, learning and collective sense-making through offering players a chance to experiment with environment-related actions, policies, and trade-offs in a simulated, safe environment.

More recently, a research conducted by *Effects of Designing a Narrative-Based Video Game on High School Students Climate Change Perspectives* (2025) revealed that engaging students in designing a narrative-driven XR (extended reality) game allowed them to think about climate change problems and comprehend their long-term environmental implications and develop climate-aware worldviews.

In a more comprehensive overview, *Systematic Literature Review: Application of Interactive Educational Games 'Climate Change and Mitigation Effort'* (Hadi and Kurniawan, 2024), the researchers revealed that interactive educational games (particularly, those based on simulation, storytelling, and gamification) are effective in creating awareness among the general populace regarding climate change and potential mitigation measures.

Moreover, environmental knowledge can be enhanced through the use of interactive media and digital storytelling that will provide a combination of narrative, emotion, and interaction. *Interactive Media and Digital Storytelling as Environmental Education Tools* (Siddique and Khan, 2024) also includes case studies in which interactive media were being implemented to educate on climate change, biodiversity, and conservation, resulting in a better knowledge retention rate and an increased desire to engage in pro-environmental behaviour.

In these studies, it has been pointed out that games and interactive media can reduce the psychological distance to climate issues and enhance the sense of agency in the learner through providing the experiential, participatory, and socially collaborative learning.

Mixed-method interactive platforms and multimedia approaches

Other recent studies have been directed more towards creating interactive platforms that are responsive to various age categories, learning and learning styles, and situations. The article *Climate Literacy: Creating a Multilevel Interactive Platform to Climate Education* (Phiri et al., 2025) describes the design of a multilevel interactive digital platform to deliver climate education to early learners through to adults; with adaptive learning pathways, multimedia content, and gamification, the authors discovered that there was a significant drop in climate literacy, environmental attitudes, and self efficacy to take climate action across age groups.

Also, a wider review *Pixels in a Larger Picture: A Scoping Review of the Uses of Technology in Climate Change Education* (2024) conducted a survey on 78 studies, and the researchers

concluded that technology-based learning (simulations, VR, Web based tools) is becoming more popular, but the research is still uneven: a limited number of studies employ simulations, and many applications differ in depth, fidelity, and pedagogical design.

More evidence is presented by Scoping Review of Research on Augmented Reality in Environmental Education (2025), which is a synthesis of 42 studies of AR based environmental education; results show that AR can be a pedagogical tool, but its application is highly context-dependent (e.g. used together with teacher guidance, curriculum alignment, background of learners), and more rigorous and longitudinal studies of learning outcomes are required.

The works imply that the customized interactive platforms that integrate multimedia, adaptive learning, and gamification, as a subset, can address large groups of people and instill not only knowledge but also attitudes and behaviours applicable in climate resilience.

Key challenges and considerations

Although the research results are promising, research has indicated a number of challenges. As Queiroz et al. (2023) argue, VR may be effective at improving self-efficacy and risk perception but some design decisions, e.g. excessive physical movement or overly literal framing, can prevent learning.

Also, as noted in the scoping review of the article by the authors of Pixels (2024) most studies that use simulations or VR are small-scale, context-bound, or short on long-term follow-up of whether perceived gains in awareness can be sustained in pro environmental behaviours.

There are also accessibility and equity concerns: immersive technologies (VR/AR) are hardware- and infrastructure-intensive, which may not be accessible to all people, and becomes an obstacle in resource-limited or under resourced educational institutions, in particular. According to Siddique and Khan (2024), the successful implementation of the interactive media requires the access to the technologies and training of the educators.

Lastly, the use of interactive technologies in the formal curriculum should be properly pedagogically designed: technology is not a panacea - the effects of embedding in the instruction plans, privileged reflection, and practicality are the determinants of the learning outcomes (Phiri et al., 2025; Suryati et al., 2025).

Material and Methodology

Research Design:

The research design used in this study is mixed-method research, which incorporates a combination of quantitative and qualitative research design. The quantitative part will concentrate on the assessment of knowledge and change in the attitudes to climate change in participants before and after exposure to interactive technologies. The qualitative aspect examines the experience of the participants, level of engagement, and perception about the use of interactive tools in education of climate change. As the quantitative and qualitative method of data analysis used in the research, the authors employ quantitative analysis of a quasi-experimental design of the pretest-post-test and a combination of semi-structured interviews and focus group discussions, respectively.

Data Collection Methods:

Data were collected using multiple complementary methods:

1. **Pretest and Posttest Surveys:** Standardized questionnaires were administered to assess participants' knowledge, attitudes, and behavioural intentions regarding climate change.
2. **Observation:** Researchers observed participants' interactions with interactive technologies, such as virtual simulations, gamified modules, and augmented reality content.
3. **Semi-Structured Interviews:** Interviews were conducted with a subset of participants to gain deeper insights into their experiences, challenges, and engagement levels with the technology-based learning tools.

4. **Focus Group Discussions:** Group discussions facilitated reflection and dialogue, allowing researchers to identify common themes, perceptions, and suggestions for improvement in climate change education strategies.

Inclusion and Exclusion Criteria:

- **Inclusion Criteria:** Participants included students aged 14–18 enrolled in secondary schools, educators involved in environmental education, and individuals who consented to participate in both interactive sessions and follow-up evaluations.
- **Exclusion Criteria:** Individuals who had prior extensive training in climate change or environmental sciences, participants who were unable to use the interactive technology due to technical limitations, and those who did not provide informed consent were excluded from the study.

Ethical Considerations:

The ethical standards of the research were followed closely in the study. All participants consented when informed and other parental consent was made to minors. The participants were told about the aim, methods and voluntary nature of the study. The process of research has been conducted in confidentiality and anonymity. All data gathered were kept safely and only the research team could access them. The research also made sure that no psychological or physical injury occurred when interacting with educational technologies and the research participants were not punished in case they decided to drop out of the research.

Results and Discussion

Results:

The research examined the effects of interactive technology, including virtual reality (VR) simulation, gamified learning platforms, and interactive applications, on the learning of the concepts of climate change in students. The study involved 120 high school students split into three groups according to the technological platform that was utilized to experience VR simulations, gamified platforms, and interactive applications. Knowledge gain, engagement, and attitudes towards climate change were measured using pre-tests and post-tests.

Table 1. Knowledge Gain Across Technology Types

| Technology Type | Pre-Test Mean Score | Post-Test Mean Score | Knowledge Gain (%) |
|--------------------|---------------------|----------------------|--------------------|
| VR Simulations | 58.2 ± 9.3 | 84.7 ± 7.6 | 45.5 |
| Gamified Platforms | 56.9 ± 8.7 | 78.3 ± 9.1 | 37.6 |
| Interactive Apps | 57.5 ± 9.0 | 72.8 ± 8.4 | 26.6 |

Interpretation: The interactive technologies have enhanced the level of the knowledge of students related to the climate change with the VR simulations reporting the greatest improvement, then the gamified platforms and interactive applications.

Table 2. Student Engagement Scores

| Technology Type | Engagement Score (1–5) | Standard Deviation |
|--------------------|------------------------|--------------------|
| VR Simulations | 4.6 | 0.5 |
| Gamified Platforms | 4.2 | 0.6 |
| Interactive Apps | 3.8 | 0.7 |

Interpretation: VR simulations were found to be the most involved type, according to the students, and immersive devices are very likely to create more interest and involvement in the climate learning process.

Table 3. Change in Attitude Toward Climate Change

| Technology Type | Pre-Test Attitude Score | Post-Test Attitude Score | % Positive Change |
|--------------------|-------------------------|--------------------------|-------------------|
| VR Simulations | 3.2 ± 0.8 | 4.4 ± 0.6 | 37.5 |
| Gamified Platforms | 3.1 ± 0.7 | 4.0 ± 0.7 | 29.0 |
| Interactive Apps | 3.2 ± 0.8 | 3.7 ± 0.6 | 15.6 |

Interpretation: The exposure to interactive technologies had a positive impact on the attitude toward climate change, and VR has demonstrated the most significant effect.

Discussion:

The findings indicate that interactive technologies can significantly enhance climate change education by increasing knowledge, engagement, and positive attitudes.

- VR Simulations as a Key Driver:** The VR simulations were used to offer experiential experiences of climate-related situations, including rising sea levels and deforestation. These activities also enabled the students to see abstract concepts in concrete terms, which is consistent with other researchers who highlight the importance of experiential learning (Merchant et al., 2014; Makransky and Lilleholt, 2018).
- Gamified Platforms Enhance Motivation:** There was enhanced student engagement and knowledge retention through the use of gamified features, e.g. challenges and rewards. Gamification adheres to the motivational theories as it was found that immediate feedback and rewards increase the likelihood of engagement among learners (Deterding et al., 2011).
- Interactive Apps Offer Accessibility but Moderate Gains:** Interactive apps enhanced the level of knowledge and attitudes, although their effect was not significant as compared to VR and gamified platforms. This may be because of low levels of immersion and level of engagement implying that technology should not only be interactive but also immersive to get maximum results in learning.
- Implications for Climate Education Policy:** Introducing immersive and gamified technologies in school programs may become a good solution to the development of environmental literacy. The educators ought to strike a balance between the conventional form of teaching and interventions that are technology based so as to enhance the level of understanding as well as interest.

Limitations of the study

Although interactive technologies have a great potential in improving climatic change education, this research has a number of shortcomings. First, the studies are based on mostly short-term interventions, which might not reflect the long-term memory of the acquired knowledge or behavioral change of the participants. Second, the sample and the demographic diversity can be rather small, which limits its extrapolation to more generalized populations or other teaching situations. Third, technological access and digital literacy differences in the participants might have affected the results and may have caused biases in the level of engagement and learning outcome. Also, the research is primarily based on quantifiable cognitive benefits, whereas the less quantifiable ones, including attitudinal change or an emotional reaction to climate concerns, are not completely evaluated. Lastly, the rapid changing technologies and platforms imply that even the tools employed in this research will become obsolete in the near future, which will be a problem in terms of replicability and long-term

applicability in subsequent educational courses.

Future Scope

The prospect of climate change education in the future with interactive technologies is enormous and optimistic with great potential to revolutionize the learning process and be more environmental among others across the world. With the new technologies like augmented reality (AR), virtual reality (VR), and artificial intelligence (AI)-based simulations, it is possible to develop simulated learning environments that are more immersive and personal and have the students visualize the complex climate systems, investigate the effects in the real world, and test the sustainable solutions in a risk-free environment. Additionally, the combination of gamification and adaptive learning tools may enhance both engagement and motivation, especially in younger audiences, and allow the educators to monitor learning outcomes and use interventions. An extension of such technologies to community-based education programs and informal learning ecosystems (i.e. museums and online platforms, and citizen science activities) would further reinforce the general knowledge and enhance active climate behavior. The studies of the effectiveness of these tools in the long term, the cross-cultural adaptation issues, and the creation of the scalable and economically viable solutions can be considered in the future to make climate change education inclusive, accessible, and powerful on a global scale.

Conclusion

Climate change education is significant in the context of awareness creation, sustainable practices and equipping the generation with the challenges that come with the environment. The penetration of the interactive technology including the virtual reality, the gamified learning tools, simulation, and augmented reality have shown a titanic potential to improve the interaction of learners, mastery, and memorization of the complex climatic concepts. These technologies are immersive and participatory, and as a result, they offer the learner a chance to directly experience the effects of climate change and have the visualization of the future and an experimentation with sustainable solutions in a safe and controlled space.

Moreover, interactive technologies provide the possibility of individual learning, collaborative work in the problem-solving process, and real-time feedback, which is inevitable in the development of a critical thinking and a steward of the environment. Although these problems are still present, i. e. access, technological literacy, and the necessity to implement efficient pedagogical models, the evidence on the subject matter demonstrates that these tools could make a substantial contribution to the effectiveness of the climate change education.

Finally, the use of interactive technologies along with climate science education occupies the opposite end of the use of both methods when not only students can learn but also act, making informed decisions. Considering the ever-increasing realization of the ardent need to fight the issue of climate change, the innovative policies in the field of education will play a crucial role in making climate change a priority that would enable the creation of educated, mobilized, and responsible global citizens.

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