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Green Gamification: How VR and AR Games are shaping the Next Generation of Climate Activists

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Abstract

Climate change is real and it has started to show its effects to us with uneven seasons, extreme temperatures, floods, and more. This increase in its criticality has redirected the attention towards role of technological revolution in promoting awareness and activism for maintaining balanced ecosystem. In terms of games, when it comes to awareness, these can be the best way we let our future generations know about the change and react responsibly. In the era of AR and VR this can be done in even more powerful ways. Green gamification is one such potential mechanism which can integrate gaming elements into eco-friendly yet realistic virtual experiences and lately this has become a potential tool for driving the proenvironmental behavior. This study explores the power of Virtual Reality (VR) and Augmented Reality (AR) games in supporting sustainable actions among individuals, especially to those reliant much on the games i.e. next generation. By making players interact with the environment such games often succeed in presenting a very environmentally supporting platform to visualize climate change's impact with deep emotional engagement and a learning atmosphere that is actionable. All of these experiences not only highlight the importance of actions but they also provide rewards and challenges which are proven to promote the significance of sustainable practices for the betterment of our ecosystem. Green gamification is a way to promote sustainability and understand the impact of climatic change in ways one couldn't imagine. This paper examines how VR and AR can align with key Sustainable Development Goals (SDGs) and can help bridge the gap between entertainment and environmental consciousness by proposing potential of gamified technologies in shaping informed climate advocates for the future.

Keywords: Augmented Reality (AR), Virtual Reality (VR), Gamification, Green, SDG, Sustainability, Climate, Environment

I. INTRODUCTION

Climate change has become a significant threat to human health, affecting physical ecosystem, nature, human, and health systems. It is responsible for the rise towards risk of deaths, no communicable

diseases, infectious diseases, and health emergencies. Climate change is also noted to have impacts on health workforce and infrastructure, shortening the universal health coverage capacity. It compromises environmental and social determinants of health, impacting clean air, water, soil, food systems, and livelihoods for organisms on the plane. It is impacting health in a myriad of ways, including by leading to death and illness from increasingly frequent extreme weather events, such as heatwaves, storms and floods, the disruption of food systems, increases in zoological diseases and food, water and vector borne diseases, and mental health issues [1].

Earth-orbiting satellites and new technologies have helped scientists see the big picture, collecting many different types of information about our planet and its climate all over the world [2]. These data, collected over many years, reveal the signs and patterns of a changing climate [2]. The IPCC's Sixth Assessment Report (AR6) indicates that climate risks are intensifying, with 3.6 billion people in vulnerable areas [3]. Low-income countries and small island states suffer the worst health impacts despite low emissions. Death rates from extreme weather are much higher in these regions. Climate change leads to health issues from extreme weather, food disruptions, increased diseases, and mental health challenges, disproportionately affecting women, children, ethnic minorities, the poor, migrants, older adults, and those with health conditions.

One technology that holds tremendous promise for transforming the way we work both involving technological advancement yet supporting the climate is augmented reality (AR). By overlaying digital information on a user's view of the real world, AR has the potential to enhance productivity, collaboration and efficiency in the workplace [4]. It blends the natural and digitally immersive worlds in one place, promising new pathways for connection and engagement. and Users can access AR with smartphones and tablets—unlike virtual and mixed reality (VR/MR), which require headsets. The term augmented reality (AR) was coined in 1992 by Boeing researcher Thomas Preston Caudell, who developed an AR application for industrial use to view some assembly diagrams [5]. Fig. 1 illustrates the Extended Reality Spectrum, which encompasses between real and virtual environments [6]. It highlights the various forms of XR technology and their positioning on this spectrum, which is as follows: *A.Real Environment* – Represented on the leftmost side of the figure, it represents the physical world, entirely free of digital elements. It is the starting point of the spectrum and is the most "real" part of the XR continuum.

B. Augmented Reality (AR) - Positioned closer to the real environment, AR integrates digital elements, such as 3D objects or data, into the real world. These augmentations are overlaid onto the real environment but allow users to interact with the physical world simultaneously.

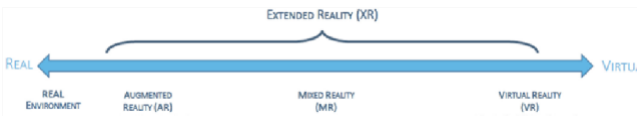

Fig. 1.Reality-Virtuality Continuum Schematic [6]

C. Mixed Reality (MR) - Sitting in the middle of the spectrum, MR blends real and virtual environments. Here, real and virtual objects coexist and can interact with one another in real-time. MR enables a deeper level of interaction compared to AR.*D.Virtual Reality (VR)* – VR represents the fully virtual

end of the spectrum. It immerses users in a completely computergenerated environment, cutting off interaction with the real world.

E.Extended Reality (XR) – XR serves as an umbrella term for all the technologies along the spectrum, including AR, MR, and VR. It encapsulates experiences that merge or transition between real and virtual environments.

Augmented Reality (AR) and Virtual Reality (VR) are innovative solutions for combating climate change. They can raise awareness, reduce emissions, and enhance environmental management through immersive experiences, virtual interactions, sustainable tourism, smart city simulations, eco-friendly lifestyle changes, monitoring and protecting the environment, and engaging stakeholders in policy change. Looking at AR's role with the lens of sustainable development, it is definite to find that AR plays a very critical role in balancing and preserving the cultural assets keeping their educational value worthy. AR has the power to reduce physical interaction with fragile heritage sites, thereby offering productive virtual reconstruction, reducing wear and tear while supporting the conservation of cultural resources, promoting economic benefits, and yet promoting sustainable and responsible tourism. The technological empowerment of AR/VR has the potential to create immersive simulations which can show climate change impacts, reduce carbon footprints, aid in wildlife protection, and build more responsive actions towards disasters and their management. It has the ability to create dynamic and engaging environment which is ought to improve students' comprehension of environmental issues and inspire them to work toward a more sustainable future [7]. The investment in integration of AR/VR technologies has not only shown promise in promoting environmental awareness but also the pockets as one can traverse through dynamic experiences while seated at one place. The simulations and experiences can enable students to experience critical environmental challenges, like deforestation, ocean pollution, air pollution, and more while motivating them to adopt pro-environmental behaviors [8].

However, no matter the technology, there are always some challenges it brings along. In case of AR/VR, challenges like algorithmic bias, ethical considerations, and the high costs of VR technology, energy usage, accessibility, and data infrastructure remain barriers to wider implementation. Irrespective of these challenges, it can inspire action, promote sustainable practices, and provide solutions to combat climate change at individual and systemic levels. Literature studies withing this area have shown that VR/AR games can increase environmental awareness by providing an interactive and immersive experience of the impacts of climate change. This technology allows players to visualize the environmental stress which can promote them to adopt sustainable actions [9]. The power of AR/VR to simulate real-world environmental challenges offers players a hands-on experience of this urgent need for climate action, which aligns with the goals of SDGs related to climate action and sustainability.

II.GAMIFICATION VS.GREEN GAMIFICATION

The usual game playing i.e. gamification, refers to the integration of the concrete game design elements, like points, leaderboards, challenges, benchmarks, top scores, and rewards, into non-game elements to increase user engagement and motivation while promoting environmentally friendly behaviors. While traditional games are meant for entertainment, the sector of games i.e. gamified systems have over a period of time evolved from just entertainment to more like actionable behaviors, user experiences, education, and more [10]. Research on gamification and serious games has become increasingly

complex, with a growing need to synthesize findings from various studies. For any game to be classified under successful gamification, it is a must that it includes "usefulness" and "hedonic value," which significantly influence users' attention and intention to engage with the system or the game. A meta-analysis conducted over games to identify what works best has highlighted that the factors listed above provide a clearer understanding of what drives user behavior [11]. Another notable study that was conducted on the systematic mapping of gamification had examined various aspects of the research field, categorizing published works into key areas like health, education, software development, and crowdsourcing. It identifies the predominant focus on proof-of-concept studies and theoretical research. From this study, it was found that the key themes that usual games rely on include user engagement, motivation improvement, and the application of gamification towards diverse domains. This study highlighted the popularity of gamification in the context of e-learning, behavioral change, and sustainability practices [12].

Evolution of the games must now shift to promoting its greener applications. “Green gamification”, an adapted form of gaming and game systems to highlight sustainability, integrates traditional game playing mechanics with environmental sustainability goals, aiming to motivate users to adopt eco-friendly behaviors. While the traditional gamification approaches focus on user engagement through gameplay elements like points, badges, leaderboards, challenges, and more, green gamification supports all these along with an additional layer of environmental outcomes which encourage actions such as energy saving, recycling, and sustainable consumption. Research in this domain have highlighted that motivations such as enjoyment, social influence, and achievement can effectively promote green consumption behaviors. The combination of emotional factors like environmental indebtedness with continuous user engagement within green gamification approaches have proven to promote long-term commitment towards sustainable practices [13]. This approach has been shown to enhance the effectiveness of environmental protection efforts by tapping into users' intrinsic and extrinsic motivations, creating a more immersive and impactful experience compared to traditional gamification.

However, studies have also identified that green gamification’s real-world impact is limited by lack of meaningful user engagement. To address such a challenge, a configurational model reliant on self-determination theory was proposed to examine how these varied motivations combine to affect engagement results. The study identified two major types of meaningful engagement like experiential i.e. driven by a positive experience and instrumental i.e. reliant on task completion. The study also highlighted that a composition of high hedonic, pro-environmental, and social interaction motivations, with low recognition, promoted experiential engagement, while instrumental engagement was primarily influenced by intrinsic motivations like sole achievement and self-expression [9]. This information proved to be the foundation for designing more effective green gamification applications by driving them through motivational factors to cater to varied user needs and outcomes. This mechanism enhances user commitment to green practices by creating personalized and engaging experiences.

III.HOW GREEN GAMIFICATION STRATEGIES COULD PROMOTE SUSTAINABILITY AND CLIMATE ACTIVISM

The awareness towards environmental issues is very high and the world has really shifted its focused and centered it towards environmental sustainability, however, it is quite challenging to propose ways that can have a lasting impact and could run for more duration. Most of the environmental solutions are

presented in a very well-structured way but their impact lasts only for a short duration i.e. traditional methods of environmental education often fail to provide emotional support or inspire long-term action. Green gamification, as a technological solution to gamified learning, when applied with VR and AR, has the potential to overcome challenges as proposed by traditional environmental solutions by creating emotionally engaging, interactive experiences that inspire users for promoting sustainable behaviors. This section proposes a conceptual framework model for such green gamification mechanisms that focus on the primary elements that any AR/VR game would demand.

At the heart of this framework are the following three elements necessary to ensure that a greener shift towards gamified learning and action of environment is supported.

A.Narrative Immersion

Storytelling is being revolutionized by VR/AR games, which offer incredibly alluring first-person experiences. Players, within any story based atmosphere, develop a sense of immersion within the game world and this is known to increase emotional engagement. Such ideas are proven to inculcate a sense of authority among players enabling them to believe that their choices matter. They make choices and act in ways that help create a unique narrative. While placing the players within the shoes of characters and experiencing other viewpoints, AR and VR has the potential to promote empathy, comprehension, emotional connections, compassion and consciousness regarding environmental concerns. Studies have also found that, while engaging with virtual characters in non-traditional ways, users might develop strong emotional connections and feel more involved into the game as if they were living with it in reality. It is equally important to note that VR/AR games play a pivotal role in easy access of complex climate data and emotionally connecting players to the issues associated with climate change, which can result into a shift from climate awareness to collective action [3]. By means of presenting highly narrative and comprehensive stories, ones that are mindful yet keep the environment lively, players within these games are ought to inspire real-world climate action which is a blend of spatial sounds, realistic visuals, with a touch of emotional tone to the story.

B.Interactive Learning

AR/VR, since its inception, has been widely and exclusively known for its interactive nature. This outstanding characteristic of replicating reality but in virtual way makes users understand and respond in realistic ways. While these games have immense interactivity, they have the potential to enable game players to understand the urgency of climate change, making it hard to turn blind eye to these critical issues. The experiences presented in such games can show players how their actions towards environment can have long-lasting effects on our planet and for an environmentally sound future. Gamified tasks provide an enjoyable way to explore complex subjects and foster pro-environmental behaviors and problem solving skills [11]. When users use such advancements, the instructiveness and the engaging learning can have positive result from overcoming challenges thereby encouraging individuals to take real-world action on sustainable practices. Visualizing real-time climate data enhances their awareness of environmental issues and the need for immediate action against global warming and resource depletion. Studies have also found that gameplay not only focuses on solving climate issues but it can promote highly interactive teamwork, inspiring players to engage in real-world advocacy [10]. Studies have also noted that exploration-based gameplay has the potential to bring curiosity about the natural world and highlights the critical challenges of preserving biodiversity in the

face of climate change. This indicates how any gamified approach through AR/VR can present interactive learning environment while aiding responsible behaviour towards ecosystem.

C.Behavioral Incentives

Now that the two elements of any gameplay are focusing on storytelling and instructiveness, with AR/VR has the potential to improve user engagement by prompting players to actively participate in environmental challenges. Another important component is the satisfaction one gets after playing any game. This component is often termed as "Behavioral incentive". Gamified tasks, such as completing missions or solving climate-related puzzles, offer a sense of achievement, which strengthens the motivation to take action and this usually acts as an incentive to the player. The joy that the players experience from the success and accomplishments, encourages them to adopt similar steps in real life, such as reducing their carbon footprint. In addition to this, the immersive and engaging experience of AR/VR games can portray real-time climate data and simulate the effects of environmental changes, motivating players to recognize the urgency of climate action. Elements in gameplay further reinforce the importance of teamwork in solving global issues, highlighting how team effort can drive change. Exploration based gameplay also sparks curiosity about the natural world, encouraging players to learn more about environmental challenges and become more involved in preserving biodiversity and promoting sustainability. Research studies have proposed that such behavioral incentives which range from intrinsic satisfaction and achievement to external rewards and problem-solving, could serve as effective mechanisms for motivating users toward real-world environmental action [9].

IV.THE URGENCY OR CLIMATE ACTION AND THE RISE OF GREEN GAMIFICATION

There is an urgent need for immediate action to address climate change as it poses a significant challenge, not only to humans but the entire environment. However, traditional educational methods lack in engaging the attention of the younger generation. Nevertheless, green gamification --an innovative approach that integrates game mechanism with sustainable environmental education, designing a fabulous solution to bridge this gap. Green gamification is best for Generation Z (Gen Z) also referred to as the digital native generation[16], as they have grown up in a world where technology and internet plays a vital role in their lives. Since the generation is highly engrossed on their screens, technology and social media, Gen Z becomes the best audience for Virtual Reality (VR) and Augmented Reality (AR) games – Green Gamification – that address environmental issues in an engaging way.

Furthermore, the boom in EdTech post-COVID has a significant advantage is addressing climate change issues. Considering the increase in demand for EdTech post-COVID, it is important that awareness about environmental issues and prevention of climate change is made available on interactive platform such as gaming platform. Using Virtual Reality (VR) and Augmented Reality (AR) games can immerse learners into sustainability through captivating simulations and real-world challenges. These platforms also provide the pupils with first-hand experience and build emotional connect with the user, letting them comprehend the real world environmental issues better, which will therefore foster their problem solving skills and critical thinking. These tools not only impart essential knowledge but also inspire meaningful behaviour change by offering instant feedback and rewards, enhancing user engagement and retention.

V. IMMERSIVE LEARNING THEORIES: EXPERIENTIAL AND CONSTRUCTIVIST APPROACHES IN ENVIRONMENTAL EDUCATION

Experiential learning and constructivist theories can truly transform how we approach climate activism through immersive environments. Experiential Learning Theory (1984) is a framework developed by David Kolb which describe how each individual learns from experimentation, reflection and first-hand experience[17]. According to the theory, experiential learning occurs through a cyclical process that involves four stages i.e. experiencing, reflecting, conceptualizing, and experimenting. Similarly, the constructivism theory is developed by Piaget and Vygotsky, which highlight that humans comprehend information better by experiencing thangs and reflecting on these experiences.

Integrating these theories with immersive technologies like Virtual Reality (VR), Augmented Reality (AR) accelerates learning through active involvement and engagement rather than passive absorption of information[18]. These immersive environments provide dynamic settings where players can develop skills and tackle problems related to climate change on their own, building a sense of responsibility and sense of authority among the players. By encountering such scenarios firsthand, players can build knowledge through exploration, experimentation, and reflection, resulting in deeper understanding and insight. Engaging experiences ignite curiosity and promote a sense of control, enabling players to actively involve themselves into preserving the environment.

For climate activists, embracing modern learning theories along with gamification deepens engagement, sharpens the players decision-making and problem-solving skills, and enhances the ability to convey complex environmental issues such as climate change, deforestation and loss of biodiversity to a wider audience, fostering greater awareness. Additionally, the knowledge and experience gained from these interactive games will inspire proactive sustainable action- an essential force in our ongoing fight against climate change.

VI. FROM AWARENESS TO ACTION: HOW AR/VR GAMES SHAPE ENVIRONMENTAL ATTITUDES AND BEHAVIOUR

The main challenge of the 21st century is to reduce greenhouse gas emissions. This is an ambitious goal that can only be reached through a collective change, and the Adoption of pro-environmental behaviours represents one of the many approaches to tackle climate change. Individuals also need to become actors in achieving this goal, which requires a significant shift in energy consumption behaviours

Most of these campaigns are conducted through traditional print and video messages and aim to provide information about environmental problems. Unfortunately, these campaigns are only partially successful as general knowledge about environmental issues seems to have only a little impact on environmentally friendlybehaviours. For instance, while large-scale mass media campaigns on the greenhouse effect did increase people’s knowledge about the issue, they failed to increase their willingness to change their behaviour.

VR tools might help to study situations that cannot be in the real world, or at least that would be difficult to study due to various constraints. The present research investigates whether the use of new technologies such as IVR can help to promote pro-environmental norms, attitudes and behavioural strategies [19]. Specifically, we are interested in assessing whether receiving energy-saving instructions

while being immersed in virtual reality is more impactful than traditional means. Virtual reality can be defined as a computer-simulated environment, mimicking real-life situations

In our work, we focus on IVR in which individuals are immersed in a three-dimensional virtual environment through a first-person perspective by wearing a head-mounted display (HMD). The IVR system tracks individuals' movements to model real-world motions in the virtual world. Specifically, to assess the effectiveness of IVR-based promotional campaigns, we ran an experiment in which we randomly assigned participants to one of the four conditions. We compare the extent to which individuals' perceived norms, attitudes and behavioural strategies to save energy at home are influenced depending on whether they participate in a traditional campaign, either through a print or a video message, or in an IVR-based campaign where the message is delivered by their doppelganger or an unknown avatar. We use an interactive scenario where an avatar (a virtual human) interacts with the user to promote sustainable actions. Moreover, we test whether energy-saving perceived norms, attitudes and strategies can be further promoted if the avatar delivering the message resembles the user, that is, if the avatar is a doppelganger. Doppelgangers are avatars that highly resemble the real self but behave independently.

VII.PROPOSING HYPOTHETHICAL SCENARIO FOR GREEN GAMIFICATION

In this paper, the authors present a hypothetical gameplay scenario that replicates the expectation of any green gamification system. The title of the game proposed is "EcoGenesis: Climate Vanguard". This AR/VR game teaches players about sustainability and motivates them to take climate action. Gamers take on the role of "EcoVanguards," expert climate protectors equipped with state-of-the-art restoration equipment and accompanied by AI partners. The game takes place in a future Earth that has suffered greatly due to climate change. Players investigate a range of biomes, including as deserts, melting polar regions, and contaminated oceans. Environmental problems specific to each biome include deforestation, increasing sea levels, and biodiversity loss. The objectives are to bring these ecosystems back into balance and stop the ongoing effects of climate change. By immersing players in genuine climate change scenarios, the game hopes to motivate them to take action and contribute to the solution.

Among the game's elements are dynamic biomes that respond to player activities, such as clearing the oceans to boost marine life or reforesting dry areas with plants. Players must make tough decisions that strike a balance between habitat protection and urban development in order to illustrate the difficulty of climate change mitigation. The game provides realtime feedback on ecosystem changes, including species population shifts and temperature variations, based on the player's choices [4]. Additionally, it integrates AR/VR for real-time climate effect visualization and immersive Eco restoration experiences.

This game empowers players to become climate change advocates by teaching them how their individual actions can have a global impact. The game simulates real-world environmental issues and offers answers, encouraging users to make sustainable decisions in their own life. By promoting the usage of renewable energy sources, cutting waste, and aiding conservation efforts, players can use these teachings to become activists outside of the game. The game's cooperative, multiplayer aspect not only promotes cooperation and group efforts but also emphasizes how important worldwide cooperation is in the fight against climate change.

VIII.THE TECH STACK OF SUSTAINABILITY: HARDWARE AND SOFTWARE ENABLERS

With the development of computer technology, new methods of user interaction with the computer and data presentation appear. Such methods include, among others, Augmented Reality (AR) and Virtual reality (VR)[20]. Both methods of data presentation differ mainly in the ratio of computer-generated images to the real world. In a nutshell, AR is when the real world is enriched with data generated by the computer, i.e. there are connections between the real and virtual world. VR occurs when computer-generated data completely obscures the real world.

Apple and Google - two giants of the mobile industry, introduced two competitive application programming interfaces sup- porting the creation of augmented reality applications for mobile devices: ARKit (September 19, 2017) and ARCore (stable release March 1st, 2018), giving users of iOS and Android devices new opportunities to create immersive applications and games [21].

As alluded to in the previous section, we believe there are a number of extremely valuable research directions that are hindered by the current standard benchmark problems. Working in these directions necessarily incurs additional overhead by forcing the researcher to create their own suitable environmentswhich can be a substantial burden if the tools of a general platform are unavailable. In this section, we highlight how the use of the Unity game engine can expedite research progress in lagging areas critical to the fields of AGI and human-AI interaction.

IX.IMPACT AND ALIGNMENT WITH SDGS

Irrespective of the fact that green gamification promoted changing individual behaviour, it also has indicated a significant impact on achieving the Sustainable Development Goals (SDGs) presented by the United Nations. The following important SDGs can be directly supported by the integration of immersive AR/VR technologies towards environmentally friendly gamified practices [14]:

A.SDG 4 – Quality Education

This goal presents the emphasis of inclusive, equitable, and high-quality education among individuals [15]. Green gamification with the help or AR and VR, by producing engaging and captivating experiences, can simplify difficult subjects like climate change thereby making them more understandable and visually appealing among students to improves educationally driven actions.

B.SDG 11 - Sustainable Cities and Communities

The difficulties presented by sustainable urban development, like resource allocation, trash management, and energy use, can be very easily understood through gamified scenarios [15]. SDG 11's objective is solely reliant on creation of resilient, sustainable urban places by urging players to make sustainable choices in a virtual city.

C.SDG 13 – Climate Action

Climate action is required and its urgency is no later than now to be treated. AR/VR can increase awareness and fasten this action by making one visualize the root cause and the potential action [15]. By using real-time climate data and offering climate related decision-making, green gamification approaches can encourage environmental awareness and proenvironmental behaviour.

D.SDG 15 – Life on Land

Biodiversity is necessary for the ecosystem to remain balanced. An imbalance can lead to disastrous changes and present difficulties in survival. Green gamification can promote the value of biodiversity and its effects on human [15]. Any game developed a result of green gamification strategy can highlight the need to preserve terrestrial ecosystems and safeguard species by letting players explore various habitats.

E.SDG 14 – Life Below Water

Marine life can only be experience realistically. For one to understand its effect, real experience is a must, but not everyone can cope with the fear of the depth of the water bodies. AR/VR with the power of its immersion mechanism can help make the users learn about the dangers that pollution, overfishing, and climate change pose to marine life by [15]. This way one can design ways to tackle and lessen threat of climate change towards aquatic life and lessen water pollution.

X.CONCLUSION AND FUTURE DIRECTIONS

Climate change is there to stay. We may possibly not be able to cut it down wholly or bring back our environment the way we want it due to immense advancement. However, there's always a way to lessen the impact of such changes. Technology has that power to become a catalyst in promoting such awareness and activities. With the support of AR/VR, green gamification can encourage awareness, participation, and action to offers a revolutionary way to solve environmental issues. Through immersive and interactive learning experiences, this tool can encourage players to adopt pro-environmental behaviours by filling the gap between digital engagement and real-world sustainability initiatives. Green games can thereby become a new way of driving climate actions with the generation of knowledgeable and environmentally supportive climate advocates because they support SDGs. The study does, however, also point out several difficulties, such as the necessity of sustainable design principles, ethical issues, and technology accessibility. The future is always brighter and with such technological ways, we can help attain the maximum benefits thereby promoting change for good. However, such games can have a cost factor making them less accessible. In order to guarantee accessibility across all demographic groups, future research and development can focus on improving the green gamification design concepts and making them cost conscious. Furthermore, green gamification that incorporates AI and real-time data might also help improve customization and offer flexible, regional answers to environmental problems. Priority must also be given to ethical issues, such as protecting data privacy and reducing the carbon imprint of AR/VR systems.

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