

# Turning Grey to Green: Engaging Gamification in Sustainability Education With Augmented Reality Technology

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**Abstract:** In recent decades, topics of sustainability and carbon neutrality are getting more attention from society and academia in the sense of urbanization and social innovation. Scholars have been proposing methods to achieve sustainability and they emphasize the importance of educating citizens about the ethics of sustainability. Also, in the educational context, there is a trend in applying gamification concepts to promote sustainability. Previous studies have demonstrated that gamification can engage students through interactive content and reward systems, so that they can be motivated to learn and apply knowledge. Nevertheless, limited articles can be found to propose methods for developing technological applications for green innovation education. In addition, scant interest has been shown to include gamification in sustainability education, especially in Hong Kong. Knowing that simulation games may raise students' curiosity to learn, we designed an augmented-reality-based educational mobile application to investigate their perception of engaging technologies and gamification in the learning process of sustainability education. In this application, there are three major components to be presented. First, various simulation games are included to educate learners with practical skills to nurture sustainable living habits. Cartoons and animations are added to better explain abstract ecological theories, and learners can interact with game characters / elements in real-time motion for an advanced gaming experience. Second, to motivate students to learn the content, digital achievement badges can be earned after winning the mini-games and they can be shared on social media platforms. It is expected that the reward system can attract students to participate actively. Last but not least, the application is hoped to engage Hong Kong citizens and the globe in the Green Deck project of Hong Kong and encourage more social involvement. With reference to the application structure, this study is expected to explore the effects of implementing games and augmented reality on education for sustainable development. Two surveys (pre- and post-surveys) would be established to evaluate the students' learning experience and knowledge acquisition on sustainability.

**Keywords:** Sustainability education, Gamification, Augmented reality, Social innovation, Simulation games, Green Deck Project

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## 1. Background

Greenhouse effect is a global climate challenge in great concern. With the development of urbanization, an increasing amount of land is being reclaimed for residential areas, leading to fewer green belts and poor urban air quality. In addition, due to economic globalization and foreign trade, there is a high demand for economic development, which inevitably leads to enormous energy consumption and carbon emissions. These actions have resulted in severe environmental pollution and degradation, which have brought detrimental effects to the world. Therefore, there is an urge for citizens to alert environment protection. According to the UN Sustainable Development Goals (SDGs) Point 13 'Climate Action', it points out that global warming will predictably cause numerous natural disaster risks, such as smog, acid rain and melting glaciers (The Global Goals, 2023a). As a result, failure to act will have irreversible consequences and will not be conducive to sustainable development. Additionally, the point 15 'Life on Land' in SDGs states that dramatic loss of forests affects biodiversity and climate change, which also affects human livelihoods (The Global Goals, 2023b). Hence, public attention is important when it comes to human quality of life.

In recent years, organizations are actively formulating countermeasures to build an ideal green future. For instance, the Chinese government's white paper "China's Policies and Actions on Climate Change," published in October 2021, proposes new development concepts to develop the economy without damaging the ecological environment (Xinhuanet, 2021). It also actively advocates citizens to develop a green and low-carbon lifestyle and carry out activities such as 'National Energy Conservation Publicity Week', 'National Low-Carbon Day', and 'World Environment Day', where these activities actively popularize sustainability education to the public (Sample Database, 2023) Furthermore, the Hong Kong government issued the first "Hong Kong Clean Air Blueprint" in March 2013 and proposed a comprehensive vehicle emission control strategy to improve roadside air pollution (Environmental Protection Department, 2023). In the European and American countries, the National Environmental Policy Law was proposed in 1969 to encourage harmonious development between people and the environment (Energy.gov, 2023).

This paper will investigate the effects of engaging gamification in sustainability education with Augmented Reality (AR) game application and evaluate whether the methods can awaken public awareness on environmental protection and promote a low-carbon green lifestyle from learning.

## **2. Problems**

### **2.1 Lack of Student Engagement in Low-Carbon Living**

According to a survey conducted by Professor Kenneth Wong and Mr. Alan Tse at Hong Kong Baptist University in 2013 ("Knowledge Development," The Hong Kong Baptist University, 2013), secondary school students in Hong Kong are concerned about the impact of climate change, but are not sufficiently engaged in low-carbon living. This indicates that low-carbon living is not yet a familiar concept in society. Furthermore, the interviewed students demonstrated weak knowledge of environmental protection and lacked engagement in sustainable activities. These results suggest that although Hong Kong students are educated about the consequences of not being green, they lack the knowledge and passion to act green. As teenagers are the main target group for education on sustainable living, there is a need to increase their awareness and engagement.

### **2.2 Inelasticity of Daily Habits**

Achieving low-carbon living requires significant changes in lifestyle and consumption habits, which is challenging for many people. According to Hong Kong's Climate Action Blueprint 2050 (Climateready.gov.hk, 2023), citizens are encouraged to change their daily habits, such as using public transportation and minimizing unnecessary purchases, to reduce carbon emissions. However, changing habits requires persistence and can be difficult for many people in the long run.

### **2.3 Deficient Sustainability Education**

Professional education and research data indicate that environmental protection education should begin with children to cultivate low-carbon energy-saving awareness from an early age and establish a social consensus (City University of Hong Kong, 2018). However, even though many online resources and physical talks are available for the public, parents may not enrol their children in these programs due to concerns about their academic performance. As a result, children may miss the opportunity to absorb essential knowledge about sustainability education during their early years, leading to a lack of understanding and concern for environmental protection.

### **2.4 Lack of Standards and Guidance in Carbon Neutrality**

In many countries, governments and companies do not establish policies or measures to reduce carbon emissions (UNEP and UNEP Copenhagen Climate Centre (UNEP-CCC), 2020). They often prioritize economic development over the importance of carbon neutrality. Some governments may refer to countries such as France as examples for reducing carbon footprints (Touratier-Muller, Machat & Jaussaud, 2019).

### **2.5 Short Summary**

Carbon neutrality is a global environmental goal that requires more efforts to be achieved. Education and training are necessary, especially among students, to raise awareness and understanding of environmental protection. To address this, we propose designing an educational environmental protection game to teach basic knowledge and skills, such as reducing carbon emissions, energy conservation, waste sorting, and resource recycling. Through an interactive approach, the game can promote environmental awareness and behaviour, encouraging students to become more conscious, responsible, and creative individuals. Our innovative approach aims to intrigue students' interest in sustainability and promote a green lifestyle in the long run, contributing to achieving carbon neutrality and environmental goals.

## **3. Literature Review**

### **3.1 Learning from Carbon-Carbon Island**

'Carbon-Carbon Island' is a mobile game designed to educate people about environmental problems, specifically carbon neutrality. The game uses simulation and educational game design to make environmental protection issues more accessible and understandable to users. It simulates different scenarios to attract players' attention, allowing them to gain a better understanding of the impact of human activities on nature. The game is mainly designed to be educational and aims to provide young people with sustainability knowledge in an engaging and interactive approach. It also encourages players to continue learning about environmental protection by earning

points to buy different digital plants in the game. Overall, 'Carbon-Carbon Island' is a creative and effective approach to educate and inspire people to act on environmental protection.



Figure 1: Screenshots from Carbon-Carbon Island



Figure 2: Screenshots from Ant Forest

### 3.2 Learning from Ant Forest

Ant Forest is a mobile application developed by Alipay, an affiliate of Alibaba Group. It is designed to motivate and encourage users to reduce their carbon footprints. It uses gamification to make the experience engaging and fun (United Nations Climate Change, 2019).

One of the main features is its realistic simulation. Users can plant virtual trees in the app's digital forest by accumulating energy through various activities, such as walking, cycling, and taking public transport. The app tracks user activities and converts them into 'green energy', which can be used to plant virtual trees. As the app users reduce their carbon footprints, the app allows them to plant more trees and grow their virtual forest. Also, the app provides educational information on different tree species, marine life, and other environmental concepts. This attempt aims to inspire app users to care more about the environment and understand the impact of their actions on the environment. Certificates will be given to users who participate with a certain amount of game time, making the experience more enjoyable by sharing their achievements on social media.

Another unique feature of Ant Forest is its real-world impact. As users accumulate energy and plant virtual trees, the company will represent users to plant real trees in desert areas. Actions in virtual world can be transferred to reality and it is much more meaningful and impactful to sustainability.

In conclusion, Ant Forest is an innovative and effective way to encourage individuals to reduce their carbon footprints by planting virtual trees. Not only playing a mobile game, but players can also actually contribute to real-life environmental protection, and it would be much significant to protect environment while enjoying the game.

### 3.3 Online Games for Sustainability Education

Learning by gamification has been promoted in years that some experiments proved that it can raise effectiveness on learning a specific concept or knowledge. A case study held in Taiwan tested students' environmental knowledge in an online gaming competition (Da Ai Television, 2022). Students were found to be enthusiastic and motivated by the awards, and they were evaluated by teachers with environment-related questions. The results showed that students can learn more effectively when games are included.

### 3.4 Benefits of Cartoon Design in Attracting Teenagers

Cartoons and comics have traditionally been perceived as sources of entertainment rather than educational tools. However, recent studies have indicated that they can effectively communicate abstract knowledge in a tangible form that is easily comprehensible to young people (Osborne, 2019).

Teenagers are increasingly drawn to cartoon-based media, such as Japanese animation and video games. Cartoon characters possess qualities that appeal to teenagers, including appearance, personality, and actions (Cooper-Chen, 2010). If designed with appropriate features, these characters can leave a deeper impression on teenagers, prompting further reflection and enhancing their understanding of the knowledge presented.

In educational application design, attractiveness is vital. Traditional learning methods can be boring, but cartoons can create a more relaxed atmosphere that feels more like ‘playing’ than ‘learning’, providing more space for recipients to engage with the materials (Kalboussi, Mazhoud and Kacem, 2016). This approach can be particularly effective for teenagers, who may have shorter attention spans and be more easily distracted.

In short, cartoons and comics are exceptional educational tools that can help convey abstract knowledge in a more tangible form that is easily understood by young people. By designing cartoon characters with suitable features, educational context can be more attractive and engaging for teenagers. In educational application design, creating a relaxing atmosphere using cartoons can be an applicable technique to promote learning and retention of information.

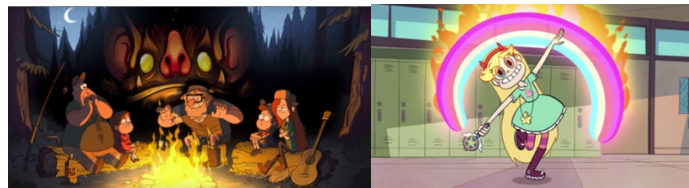


Figure 3: Cartoon UI design

### 3.5 Green Tech

Green Tech is a new concept that encompasses technologies which are environmentally friendly (Ishak, Jamaludin and Abu, 2017). With the world facing serious environmental problems due to human activities, the importance of green tech is becoming increasingly apparent. Green technologies offer many benefits, including reducing energy and water consumption, lowering waste production, decreasing our carbon footprint, and increasing business efficiency by reducing costs, improving product design, and creating new jobs (Irvani, Akbari and Zohoori, 2017).

One advantage of green technology is the reduction of waste and improvement of recycling. By implementing green technology, companies can decrease the amount of waste they generate and mount the use of recycled materials (Haleem et al., 2023). This helps conserve natural resources and reduce the amount of waste that ends up in landfills and oceans.

Green technologies can enhance technology-related efficiency and lower business expenses by reducing energy and water consumption, helping to promote sustainability in the business world. Additionally, green technologies can help reduce social issues, power consumption, and create more employment opportunities. Overall, Green Tech is an essential concept for entrepreneurs and the direction for technological development to create a more sustainable future for ourselves and future generations.

## 4. Research Methodology

### 4.1 In-depth Interviews (IDI) and Focus Group (FG)

A total of 4 IDIs and 1FG were conducted on 10-13 May 2023. Each IDI and FGI lasted for 1 hour and 2 hours respectively.

Table 1: In-Depth interview and focus group

	IDI1	IDI2	IDI3	IDI4	FG
<b>Respondent profile</b>	S4, Male Liberal Business subjects English-medium class HK Island school	S4, Female Liberal Science subjects Chinese-medium class Kowloon school	S5, Male Liberal Business subjects English-medium class HK Island school	S6, Male Science Business subjects Chinese-medium class	Secondary school teachers, 3 F & 2M 3 teaching English-medium class and 2 teaching

	IDI1	IDI2	IDI3	IDI4	FG
				Kowloon school	Chinese-medium class
<p><b>Students: All have experience in developing good environmental habits.</b></p> <p><b>Teachers: All have experience in environmental conservation work</b></p>					

## 4.2 Define

### 4.2.1 Identify subtle reminders as key to environmental protection

According to the interviewed students, developing good environmental habits is an ongoing process that requires subtle and continuous reminders. They suggest starting with small but meaningful actions, such as reducing waste and using reusable bags and water bottles. The students emphasize the importance of raising awareness and promoting environmental education in schools, communities, and families to foster a culture of sustainability and responsibility.

### 4.2.2 Advocate software or game for environmental education

The interviewed teachers suggest that using software or games can be an effective approach to promote environmental protection and cultivate good environmental habits among students. They believe that electronic forms can make learning about environmental issues more engaging, interactive, and accessible, and can also help students develop digital literacy skills. The teachers emphasize the importance of developing electronic materials that are age-appropriate, culturally relevant, and aligned with the curriculum. The teachers also suggest that software or games can encourage students to adopt and sustain good environmental practices, such as reducing waste, conserving energy, and using sustainable transportation.

### 4.2.3 Identify game themes for environmental education

The interviewed teachers express that environmental education games and apps with themes such as tree planting, climate change, renewable energy, food carbon footprint, and daily carbon reduction behaviors are highly relevant for cultivating good environmental habits among students. They find that these games offer diverse gameplay and innovative interactive forms, such as gamification, drag-and-drop, and gesture recognition, which can keep students engaged and motivated, enhancing their learning outcomes. The teachers believe that gamification can be used to encourage students to turn environmental protection into practical action and make our world a better place.

## 4.3 Prototype

This game design provides users with a variety of environmental games to experience and learn about environmental conservation. The games are designed to be both entertaining and educational, allowing users to engage with environmental issues in an interactive and immersive way. Through games, users can learn about topics such as renewable energy, waste reduction, and sustainable living. This game design aims to raise awareness and encourage positive environmental action in public.



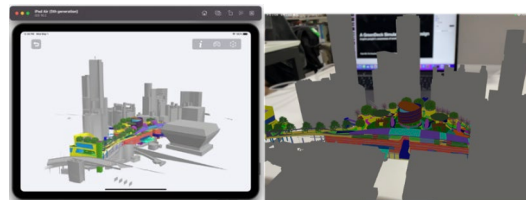
Figure 4: Game menu

### 4.3.1 AR/VR green deck

This feature introduces users to the benefits of tree planting, including reduced air pollution, energy conservation, improved water quality, and enhanced wildlife habitats. In the context of Hong Kong's Hung Hom Submarine Tunnel, tree planting can help alleviate air pollution in a particularly problematic area. Through virtual and augmented reality, students can learn about the importance of green tree planting and become more

engaged in environmental conservation. By increasing awareness and understanding of environmental issues, we can work towards a more sustainable future.

**Table 2: Game theme design graph**



**Figure 5: Screenshots for AR/VR Green Deck**

#### 4.3.2 Game 1 – The Challenging Climate in Hong Kong Sort In Out

This feature requires users to understand dangers and opportunities facing in Hong Kong's climate. Through interactive question-and-answer mini-games, students can gain a better understanding of Hong Kong's climate.

The rules of the game are as follows:

- There is a time limit of 1 minute.
- The user must select the correct answer. If the answer is correct, points will be added to the account, and points will be deducted for incorrect answers.
- Failing to answer three questions correctly will result in failure.

Overall, this feature is designed to help users better understand the challenges and opportunities facing Hong Kong's climate. By interacting with mini-games, students can learn in a fun and engaging way, while also gaining valuable knowledge about environmental issues.

#### 4.3.3 Game 2 – Every Step Counts

This feature allows users to learn common environmental protection techniques, such as using cloth bags for shopping, avoiding waste, and other behaviors. By answering questions, users can increase their awareness of daily life environmental protection expertise.

The rules of the game are as follows:

- The system generates questions with different options for everyday life-saving tips.
- Users receive reminders and learn more about environmental protection knowledge when they select correct or incorrect answers.

This feature is designed to help users learn practical environmental protection expertise that can be applied in their daily lives. By answering questions and receiving feedback, users can increase their awareness of environmental issues and develop sustainable habits. By promoting environmental protection knowledge in a

fun and attractive conduct, this feature can inspire positive changes and encourage users to keep their habits in sustainable lifestyles.



Figure 6: Screenshots from Game 1 – The Challenging Climate in HK Sort In Out



Figure 7: Screenshots from Game 2 – Every Step Counts

#### 4.3.4 Game 3 – Understand Fuel Types

This feature allows users to learn about renewable and non-renewable energy sources, understand the reliability of different fuels, and increase environmental awareness.

The game rules are as follows:

- The system generates different fuels, such as coal, natural gas, and oil.
- Users choose different fuels and judge their reliability instantly.
- Correct answers earn points, while incorrect answers result in failure.

This feature is designed to help users understand the reliability of different energy sources and promote a better understanding of environmental issues. By learning about renewable and non-renewable energy sources, users can consider more choices on their energy consumption and reduce their personal impact on the environment.

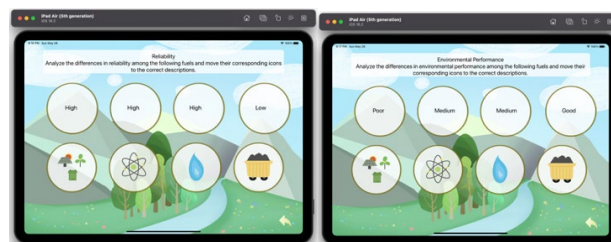









Figure 8: Screenshots from Game 3 – Understand Fuel Types

#### 4.3.5 Achievements design

In this feature, users can exchange rewards for different roles using points and share them on various social media platforms. Users can earn tokens by winning games and exchange medals with the tokens. Those medals can be shared on social media platforms for sharing.

This feature is designed to incentivize users to engage with the app and promote sustainable behaviours. By earning points and exchanging them for medals, users can feel a sense of accomplishment and be motivated to continue using the app. By sharing their achievements on social media platforms, users can also inspire others to make positive changes in their own lives.

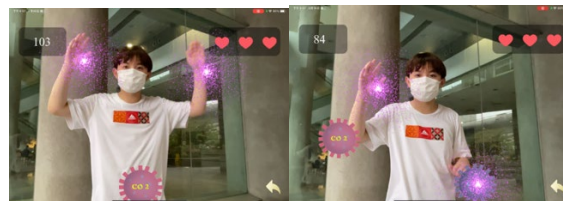
**Table 2: Achievements design**

 <p>No waste</p>	 <p>Save electricity</p>	 <p>Eco-friendly travel</p>
 <p>Eco Bag</p>	 <p>Water resource</p>	 <p>Love the earth</p>
 <p>Caring environment</p>		

#### 4.3.6 AI Hand landmarks Design

Hand gesture interfaces are becoming increasingly popular as a method of interacting with digital devices. These interfaces provide the advantage of convenience, allowing users to communicate with devices in the most natural way possible. This technology has shown great potential in human-machine interaction and is becoming more prevalent in games and other applications (Ertugrul, Li and Sheng, 2020).

One of the key advantages of hand gesture interfaces is their flexibility and richness. These interfaces allow for a wide range of gestures to be used, providing users with a more intuitive and engaging experience. This can be especially beneficial in games, where precise and efficient targeting can be crucial for success. By applying AI landmarks, players can easily control the cursor and use it to efficiently target specific objects. This helps to enhance the user's experience and make the game more promising.



**Figure 9: Demonstration on AR interactive game**

#### 4.4 Evaluation

The evaluation of the environmental education game showed promising results. A total of 130 students were invited to experience the game by downloading it. Pre- and post-surveys were conducted to evaluate their environmental knowledge. The results showed a significant increase in the students' overall scores on the post-survey compared to their pre-survey scores after playing the game. Specifically, there was a notable improvement in their understanding of topics related to renewable energy, waste reduction, and sustainable living. Furthermore, the students reported a higher level of interest and motivation in learning about environmental issues after playing the game. The game's interactive and engaging features, such as its gamification elements and user-friendly interface, were positively received by the students. These findings suggest that the game was effective in promoting environmental education, increasing students' knowledge of environmental issues, and fostering their interest and motivation in learning about environmental sustainability. In summary, this initiative demonstrated the potential of using games as a tool for environmental education and emphasized the importance of engaging and accessible approaches in promoting environmental awareness among young generations.

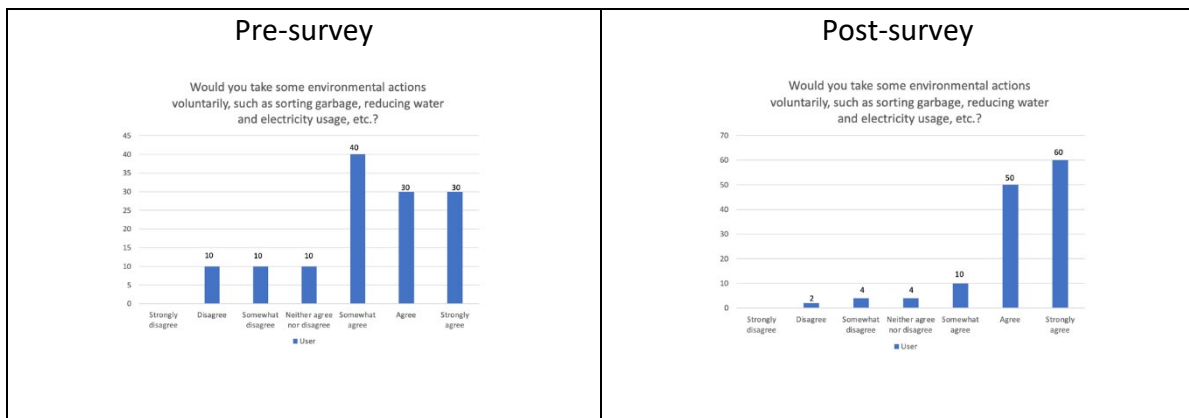


Figure 10: Bar graphs for pre- and post surveys on willingness to act green

### 5. Conclusion

#### 5.1 Limitation

One limitation is that the app's game themes may require regular updates to stay current with users' preferences and interests, particularly for younger users. Another potential limitation could be the technology limitations of the user's device, such as processing power or storage capacity, which may affect the app's performance and functionality. It is important to consider these limitations when designing the app and to ensure that it remains accessible and engaging for all users.

#### 5.2 Summary

The completed game advocates for environmental protection and encourages environmentally friendly behaviors to address the world's pressing environmental issues. Through the game, players can adopt low-carbon lifestyle habits, promoting ecological balance and environmental health. The game also provides information about the benefits of environmental protection and the importance of daily environmental habits. The game design is accessible and easy to use, inspiring a new generation of environmentally conscious individuals committed to protecting our planet.

#### 5.3 Recommendation

To attract users and enhance the learning experience, we could consider incorporating elements of the metaverse or popular gamification strategies that appeal to younger audiences. This could help create a more engaging and immersive experience for users, while also promoting environmental education and awareness.

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