

Leveraging Gamification in E-Commerce for Climate Change: A Persuasive Technology Acceptance Model (TAM) Approach

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Abstract. The rising global population has intensified climate change, with 2022 evidencing the highest record of greenhouse gas emissions, at 53.79 billion metric tons. By 2024, the average surface temperature has also surpassed the 1.5-degree threshold. Despite increasing occurrences of climate change, there exists a gap between knowledge and acting towards mitigating climate change. This study integrates mini-games and gamification into an e-commerce mobile app as (in) direct persuasive mechanisms to reduce individual carbon footprints and increase willingness to mitigate/act. Hypotheses are: (1) climate change-oriented gamification in e-commerce will increase awareness of climate change; (2) gamification will encourage individuals and communities to act towards reducing climate change; (3) gamification, e-commerce, and a carbon footprint calculator will help reduce carbon footprint. Alpha-beta testing based on the Technology Acceptance Model, finds that the biggest difference between pre-post-game introduction is personal carbon footprint, followed by the level of willingness to engage with climate change, possible initiatives for mitigating climate change, and cause-effect purchase decisions in the 'Shop' feature. The transition from a simple calculator to a visualized carbon footprint report, the change of real-life challenges into interactive mini games, highlights the importance of direct contextualization and immediate relevance. However, the study faces limitations, due to small sample size, and reliance on generalized emission data, which affects the accuracy of the carbon footprint calculator.

Keywords: Design thinking · metaverse · climate change · carbon footprint · e-commerce-mini-games · gamification

1 Introduction

In recent years, climate change has grown into a critical global concern. Its adverse effects range from fluctuating weather conditions that jeopardize agricultural output, to escalating sea levels that heighten the perils of floods due to excessive rainfall [1, 2]. The World Health Organization has also reported that climate-induced floods have affected over 2 billion people globally from 1998 and 2017 [2].

Additionally, climate change has contributed to other natural disasters, including heatwaves, droughts, and storms, causing environmental destruction, and threatening

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human life [2]. Wildlife and ecosystems have also been significantly impacted, with climate-driven disruptions facilitating the spread of diseases among wildlife and the intrusion of non-native species [3]. Hence, the United Nations has regarded climate change as requiring urgent immediate action [4].

Despite the widespread awareness of climate change, the lack of accessible information on actions that contribute to individual carbon footprints hinders efforts to mitigate climate change [5]. This gap between awareness and action thus underscores the need for tools that help individuals understand and reduce their carbon footprints, fostering responsible behaviors to combat climate change. The use of technology has emerged as a possible method for educating users about climate change. Technologies such as Augmented Reality (AR) and Virtual Reality (VR) have gained popularity in their ability to create immersive learning. However, despite their potential, AR and VR remains as expensive solutions for widespread adoption, limiting their accessibility and scalability for educating about climate change [6].

In contrast, e-commerce has risen in popularity, with approximately 2.71 billion users globally [7]. Major platforms such as Shopee and Lazada have successfully utilized gamification strategies, offering rewards such as e-commerce coins for discounts to enhance user engagement and encourage positive behaviours. Building on this trend, this study proposes a solution that bridges the business (e-commerce) and tech (development of games and related innovations) sectors to address climate change. By leveraging e-commerce and gamification as tools for direct persuasion, the goal is to encourage users to act for climate change. Through gamification, users can virtually experience the positive consequences upon performing environmentally friendly behaviours, fostering intrinsic motivation. This process can lead to self-persuasion, where individuals internally adopt sustainable behaviours or attitudes, rather than relying on external incentives [8]. By doing so, the project aims to:

1. enhance individual awareness of climate change by educating users on their carbon footprint, emission sources, and environmental consequences,
2. increase individual or community efforts to reduce carbon footprint,

Specific aspects of investigation are based on two theories. First, Cognitive Load Theory (CLT) highlights that pattern identification helps learning, memory and understanding. Moreover, game mechanisms/elements decompose chunks of information into smaller parts [9]. Hence, complex information can become more digestible and easier to remember. Second, the Gamified Learning Theory (GLT) [10] suggests that game-like features, such as challenges, rewards, and feedback, can influence attitudes and behaviors in non-game contexts. Hence, it makes sense to utilize scenario-based challenges/games and gamification to achieve the above objectives.

The research questions formulated for this paper are as outlined:

1. Will climate change-oriented gamification in e-commerce increase awareness of climate change?
2. Will gamification in e-commerce encourage individuals and communities to act more towards reducing climate change?
3. Will gamification, e-commerce, and the integration of a carbon footprint calculator contribute to actions that would reduce carbon footprints?

2 Literature Review

2.1 Climate Change

The United Nations defines climate change as long-term alterations in temperature and weather patterns. This phenomenon is strongly linked to the release of GHGs, which are heat-trapping atmospheric gasses composed from carbon dioxide, methane, nitrous oxide, and other chlorofluorocarbon gasses [11]. Research has highlighted the importance of maintaining a balance of natural GHGs in Earth's atmosphere to support life, with carbon dioxide playing a key role in absorbing and radiating heat [12, 13]. However, human activities since the Industrial Revolution have significantly increased carbon dioxide emissions, contributing to global warming and climate change [11]. Statistics have shown that since 1990, carbon dioxide emissions have surged by over 60%, to 37.55 billion metric tons in 2023, marking the highest emission record to date [14].

Climate change results from a combination of natural phenomena and human activities [13]. Natural causes, like volcanic eruptions and tectonic movements, can influence Earth's temperature; however, their impact on climate change is minimal due to their slow pace [15]. In contrast, anthropogenic climate change, driven by human activities, is the main contributor to the observed increase in global warming. Specifically, activities such as the combustion of fossil fuels releases carbon dioxide into the atmosphere, significantly increasing carbon emissions. Human activities, including energy consumption in buildings for heating and cooling appliances, emit much carbon [16].

Moreover, population growth amplifies carbon emissions, as increased demand for consumer goods and agricultural products leads to requirements of higher industrial production, which are often powered by fossil fuels. Similarly, waste production (like food and yard waste), and transportation choices are significant contributors to GHG emissions [17, 18]. Landfill waste decomposition releases methane and carbon dioxide, collectively known as landfill gas [17]. Transportation is also largely dependent on petroleum-based fuels, which accounts for up to 15% of global GHG emissions [18].

2.2 Carbon Footprint

Carbon footprint refers to the total greenhouse gas emissions resulting from individual and business activities [19]. Greenhouse gases include methane, and nitrous oxide, which are carbon dioxide equivalents (CO_2e). The use of CO_2e standardizes the measurement of GHGs based on their different global warming potential (GWP), allowing for a consistent assessment of their collective impact [20].

To calculate carbon footprints, established protocols such as GHG Protocol and Life Cycle Assessments are used for organizations. ISO 14064 provides a standard method for quantifying organizational emissions, involving the multiplication of activity data by emission factors [20]. The World Wildlife Fund (WWF) and The Nature Conservancy, estimate personal carbon emissions.

Equation (1) is a generic formula for calculating the carbon footprint, where activity data is the quantitative measure of activities conducted (such as kilograms of waste disposed), while emission factor refers to the measure of emissions produced for every

unit of activity (e.g., kg of CO_2e per ton of waste disposed).

$$Carbon\ Emission = Activity\ data \times Emission\ Factor \quad (1)$$

2.3 E-commerce

In recent years, e-commerce usage has increased tremendously due to its benefits offered [21]. According to Shopify, users aged 18 to 34 are the primary users for e-commerce, with 67% increasing their expenditure post-pandemic [22]. In Malaysia, the youth dominate e-commerce usage, with individuals below 20 taking up 27.4% of the total, and those in their 20 s making up 21.1% of the users [23]. To enhance user engagement, e-commerce such as Pinduoduo, Shopee, and Lazada have integrated gamification, for example Duo Duo Orchard, Shopee Bubble, and Lazland. Shopee is now the first among Southeast Asia's leading e-commerce platforms and is the most popular in Malaysia, with over 60 million visitors every month [24]. Hence, this study has chosen Shopee to emulate.

2.4 Games and Gamification

Games provide interactive experiences with predetermined rules, goals, a measurable progression system, and a clear conclusion to end the game [25]. In contrast, gamification involves integrating elements frequently found in games into non-gaming contexts to accomplish a particular goal or to encourage specific behaviors. Gamification plays a significant role, with research stating that it builds an environment where individuals are naturally driven to interact with content relevant to a specific domain, thereby facilitating behavior modification towards more desirable outcomes [26]. Common gamification elements include rewards, points, leaderboards, virtual currencies, and progress bars.

Gamification in E-commerce. Gamification in e-commerce is projected to be integrated into 87% of online stores within the next 5 years [27]. Numerous studies have highlighted the positive impacts of gamification in e-commerce. For example, a systematic review by Azmi et al. [28] found that rewards, badges, and leaderboards are the most implemented gamification elements, which contribute to successful integration in e-commerce. These elements, specifically rewards like coupons and discounts, have been found to exert a psychological effect on consumers, promoting loyalty and return visits. Similarly, another study supported the prominence of rewards, points, badges, and leaderboards in e-commerce gamification [29]. Numerous studies on Shopee's gamification features have demonstrated their effectiveness in enhancing user engagement, where participants reported increased satisfaction and interest as they accumulated rewards, triggering positive reinforcement for prolonged platform use [30–32]. Users also expressed their preference for challenges in games, noting that it motivated them to play longer, and contributed to their satisfaction and retention [30, 31].

Gamification for Climate Change. Douglas and Brauer [26] found that gamification in applications promoting sustainability and climate change awareness is more effective in encouraging sustainable behavior compared to other behavior modification techniques.

Specifically, apps that integrated rewards and feedback were more successful in engaging users than those focused solely on informational content. Another study emphasized the importance of combining emotional storytelling (pathos), ethical responsibility (ethos), and factual decision-making (logos) to enhance the impact of gamified climate change applications. Similarly, Novo et al. discovered that integrating gamification into sustainability apps increased users' environmental awareness and motivation for sustainable practices [33]. However, they noted that the lack of sufficient theoretical content limited participants' knowledge growth. Thus, these studies highlight the need to balance gamification elements with educational content to maximize its effectiveness.

3 Methodology

3.1 The Self-Determination Theory (SDT)

SDT identifies 3 core factors that drive human motivation and behavior, i.e., autonomy, competence, and social relatedness [34]. *Autonomy* refers to the need for individuals to feel self-governed. *Competence* refers to the need to feel successful in one's actions. SDT explains that people are more likely to engage in behaviors when they feel socially connected (social relatedness).

3.2 The Technology Acceptance Model (TAM)

The Technology Acceptance Model (TAM), introduced by Fred Davis, provides a theoretical framework for understanding how users adopt and engage with new technologies [35]. This study utilized constructs from TAM 1, 2 and 3 to evaluate user acceptance of the prototype (alpha testing) and its subsequent development (beta testing). As shown in Fig. 1, the evaluation framework was structured around key TAM constructs, including *perceived usefulness, perceived ease of use, attitude towards using, and behavioural intention to use.* Each construct was operationalized through a questionnaire, with responses collected using a 5-point Likert scale, ranging from "strong disagree" to "strongly agree".

3.3 Software Development Lifecycle

This project adopted an Iterative Incremental Prototyping Methodology. After initial ideation and problem definition, game features were derived from the literature reviewed, informed by Cognitive Load Theory and Gamified Learning Theory. These requirements were later translated into prototypes using Figma. Alpha testing was conducted on the prototypes to evaluate user acceptance and behaviour through a TAM-based questionnaire. The insights from the alpha testing informed design refinements, which were implemented into the development phase. Finally, the system underwent beta testing to validate its alignment with user needs using the same TAM framework.

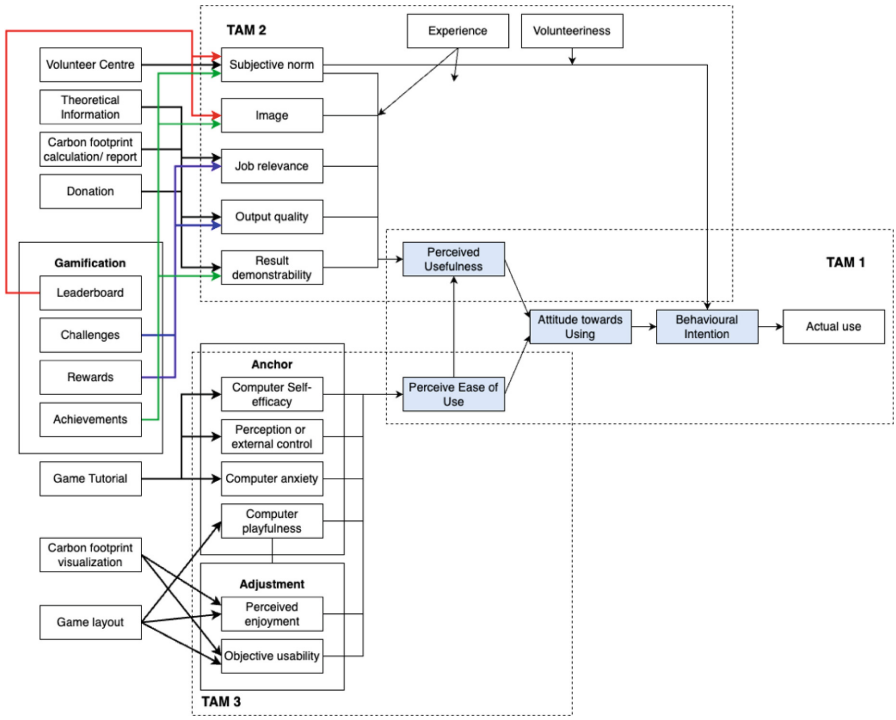

Fig. 1. TAM framework showing core constructs and relations to this study's key components.

3.4 Prototype Design

Figures 2 and 3 shows the app prototype. The game includes 5 main features: Shop, Challenges, Leader board, Achievements, and Coin Store. As shown in Fig. 3, the Leader board promotes engagement through point-based rankings, while the Challenges encourage real-world sustainable actions, such as using public transport, with rewards granted upon proof of completion. Purchases made in the Shop are reflected in the game's virtual environment (graphically and carbon footprint amount) to simulate their environmental impact; for example, buying an energy-related product updates the energy source in the user's in-game 'city'.

4 Results and Discussion

The survey was conducted via Google Forms and assessed participants' awareness and intentions before and after interacting with the game, in line with TAM constructs. The survey collected a total of 37 responses for alpha testing, and 40 for beta testing.

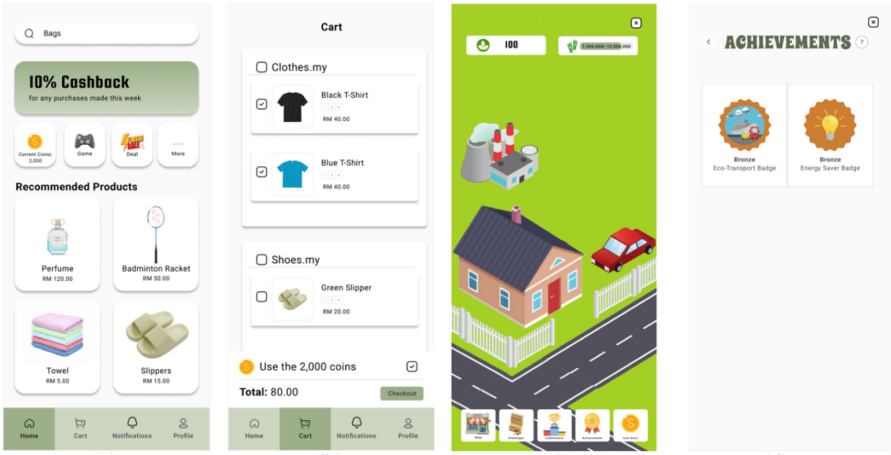

Fig. 2. Overview of the e-commerce and game prototype. (a) The e-commerce homepage, displaying coin balance, product listings, and access to the game. (b) Cart page where coins can be redeemed for discounts (1 coin = RM 0.01). (c) Game interface, accessed via the homepage. (d) Achievements page, accessed through the game menu.

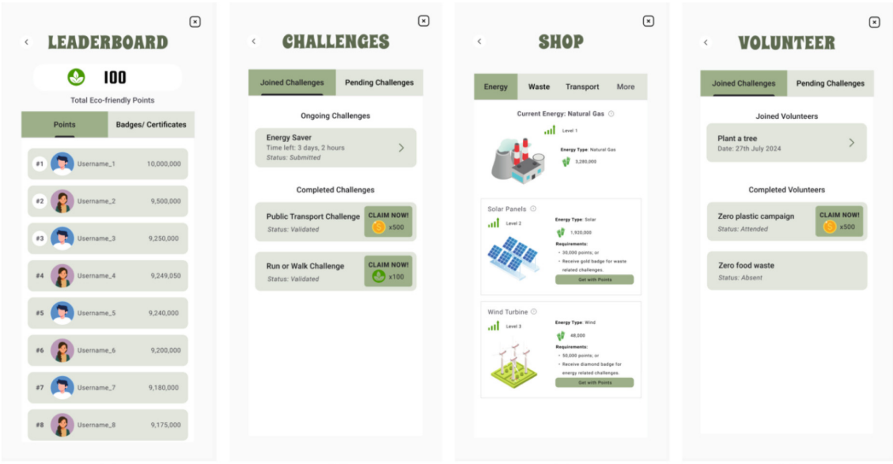

Fig. 3. Additional features of the game. (a) Leader board page displaying user rankings based on eco-points and achievements. (b) Challenges page showing ongoing and upcoming challenges with deadlines. (c) In-game Shop offering sustainable products categorized under energy, waste, transportation. (d) Volunteer page, showing available volunteer opportunities.

4.1 Alpha Testing

Results Based on TAM. Table 1 shows the results from alpha testing, with calculated average ratings from 1 to 5 (5 being the highest). For ***perceived usefulness***, the average

score for all measured factors of user's awareness exceeds 4 (post-introduction of the game), which is a very positive sign. The biggest difference between pre-post game introduction is attributed to awareness of personal carbon footprint (1.24). This difference may be due to contextualization and immediate visualization of the causes and consequences, or impacts based on the personal carbon footprint.

Table 1. Alpha Testing Results.

TAM construct	Item assessed	Mean		Difference
		pre-introduction	Post-introduction	
Perceived usefulness	Awareness of causes and consequences (Shop's theoretical information)	3.78	4.08	**0.30**
	Awareness of climate initiatives (Challenges/Donation/Volunteer)	3.59	4.11	**0.52**
	Awareness of personal carbon footprint (Progress Bar)	2.92	4.16	**1.24**
Perceived ease of use	Understandability of carbon footprint	–	3.95	–
	Comprehension of theoretical content	–	3.89	–
	Challenges/ Donation/ Volunteer	–	3.77	–
Attitude toward use	Challenges/ Donation/ Volunteer	–	4.19	–
	Shop feature	–	4.05	–
	Future game use	–	4.05	–
Behavioral intention to use	Reward-based challenges	–	4.08	–
	Donations/ Volunteer feature	–	3.41	–
	Willingness to use Climate Guardians	–	3.89	–
	Intention to use Shop	–	3.89	–

The carbon footprint calculation received the highest score for ***perceived ease of use***. However, participants noted that the carbon footprint visualization appeared confusing. Since the calculation was displayed as a progress bar, it appeared to the participant that the goal was to fill the bar, when the objective was to reduce it. Overall, participants reported positive ***attitudes towards using*** Climate Guardians and its features, as indicated by the average scores.

For ***behavioural intention to use***, the intention to engage in challenges received the highest score, suggesting a stronger preference for individual-based activities as compared to group-based activities (donation/ volunteer), which scored the lowest. In

contrast, the Shop feature received a score of 3.89. Participants noted that overly wordy texts have reduced their engagement, which may have influenced this rating.

4.1.1 General Feedback

Participants provided feedback on the app. This was adapted to the developed app, as shown in Fig. 4. The key revisions made based on the alpha feedback were:

- Text-heavy sections were replaced with visual comics and graphics.
- Carbon footprint progress bar was changed to a pie chart with numerical data.
- Complex real-life tasks were redesigned as mini-games (e.g., trash sorting).
- Volunteer section was updated with direct organization's contact information.
- Donation achievements (certificates) were added to increase trust and encourage engagement.
- Game tutorial was added to improve ease of use.
- Carbon footprint reduction thresholds were added, for users to unlock rewards like coins to improve gameplay engagement.

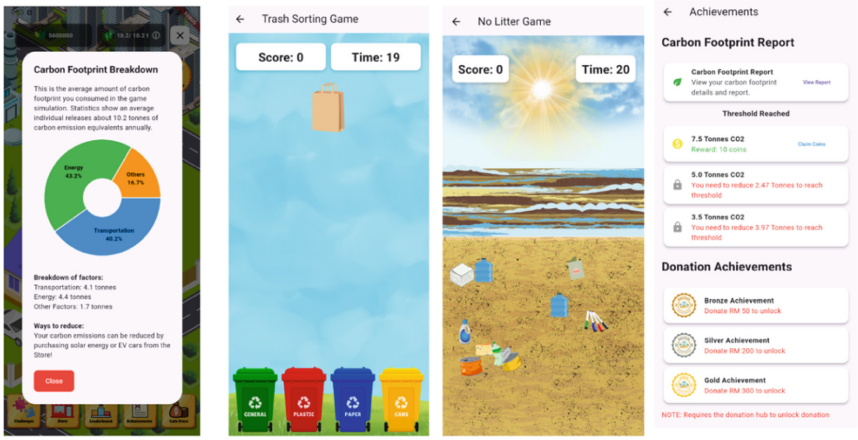

Fig. 4. Screenshot of developed app: carbon footprint calculation, mini games, and achievements. (a) Carbon footprint visualizations. (b) Trash sorting mini game. (c) Trash collection mini game. (d) Achievement page displaying carbon footprint reports, certificates or thresholds.

4.2 Beta Testing

Results Based on TAM. The comparison between the alpha and beta testing results shows consistent increase in scores (Table 3). In terms of ***perceived usefulness***, the carbon footprint visualization and reports received the highest scores, indicating that visual tools like pie charts were effective in increasing user awareness of their carbon

footprint and environmental impact (Table 3). The rewards-based challenges were also rated highly (4.10), reinforcing the motivational effect of rewards in maintaining participation. However, motivation by leader board scored relatively lower, at 3.85, suggesting that friendly competitions did not resonate as strongly with users.

For ***perceived ease of use***, all features were rated above 4, suggesting positive user experiences in navigating the app. Regarding ***attitudes towards using,*** the reward-based challenges and theoretical content (in Shop) were the top 2 high scores. The largest improvement was observed in attitudes towards 'Shop', suggesting that changing text to graphic delivery of theoretical information improved user reception.

Additionally, for ***behavioural intention to use***, the donation or volunteer center increased by 0.49 points compared to the alpha testing phase. This improvement suggests that changes, such as greater transparency and highlighting recipient organizations for donations may have increased user trust and usage intentions.

4.2.1 General Feedback

This section revealed that participants felt empowered to engage in climate change mitigation initiatives after using the game, with 40% agreeing, and 40% strongly agreeing, and an average score of 4.20. Thus, the results indicate a positive attitude towards taking action following the gameplay.

4.3 Discussion

4.3.1 Analysis of Research Question 1

Will climate-change-oriented gamification in e-commerce increase awareness and learning about climate change?

In line with the Gamified Learning Theory (GLT) [10] and Cognitive Load Theory (CLT) [9], the developed game has implemented **clear goals** through *donation thresholds* and *carbon footprint reduction targets.* Users also receive **immediate feedback** in mini games e.g., the trash sorting game, where they can immediately see whether their sorting of trash is correct or incorrect through addition or reduction of points and visual cues. Additionally, **continuous reinforcement** is present in the game. Rewards e.g., e-commerce *coins, virtual badges, and certificates* are awarded to users upon showing positive climate-related behaviors.

From Table 2, initially, average ratings for awareness of carbon footprint, and causes and consequences were below 4. But after/post-introduction of gamification elements, the scores increased to 4 and above, indicating increased awareness. This concurs with [36]'s findings. [36] find that goals, feedback and continuous reinforcement mechanisms increase awareness because an enjoyable learning process of the content and positive reinforcement encourages active engagement/deeper absorption and repeated participation; eventually leading to long-term retention of knowledge. Hence, climate change-oriented gamification in e-commerce, which are **goal-oriented**, and includes **challenges** with **immediate feedback** and **continuous reinforcements**, augmented by *carbon footprint visualizations*, and *donation opportunities*, can increase participants' awareness of climate change.

Table 2. Beta Testing: Change in Perceived Usefulness Before and After Game Introduction.

Pre-introduction of game		Post-introduction of game		Difference
Awareness of carbon footprint	2.7	Awareness of carbon footprint through visualization and report	4.23	1.53
Awareness of causes and consequences	3.65	Awareness of causes and consequences through Shop's theoretical information	4.10	0.45
Willingness to take climate change initiatives	3.35	Willingness to take initiatives after learning through challenges	4.18	0.83

4.3.2 Analysis of Research Question 2

Will gamification in e-commerce encourage individuals and communities to act more toward reducing climate change?

Autonomy. Table 2 indicates that initially, participants are only moderately willing to act (average score of 3.35). However, after integrating gamification in the e-commerce-cum-climate change game mobile app, willingness to engage in mitigation efforts increases to 4.18. This highlights that rewards (i.e., e-commerce coins) and achievements (i.e., certificates) serve as extrinsic motivators, or indirect persuasion mechanisms [37, 38]. Though certificates may act as external incentives, but over time, these extrinsic motivators can encourage self-persuasion by prompting users to reflect on their actions and internalize the value of sustainable behaviors. For example, earning a certificate for donations might initially be driven by the desire for recognition (extrinsic motivation), but reflecting on the achievement can lead individuals to see themselves as environmentally responsible, thus reinforcing intrinsic motivation. This is in accordance with [39], which suggests that rewards can positively influence users' game enjoyment, contributing to their intrinsic motivation to conduct climate actions.

Additionally, the intention to use the *donation* feature increases from 3.41 in alpha testing to 3.90 (Table 3, TAM Construct: Intention to Use) after introducing *certificates* as rewards in beta testing. The finding suggests that gamification elements in our integrated e-commerce-climate change game mobile app, has successfully increased motivation for climate action through our **direct and indirect persuasion** mechanisms.

Competence. Based on SDT [34], as users are increasingly aware, their competence level increases. Achievements, points and leader boards in the developed app function as tools that enhance user's competence, as they give immediate feedback and reinforces a sense of progress [37]. When users observe measurable increases in outcomes, they experience feelings of success and mastery. Consequently, users are more likely to take part in activities and persist in them, as they find the experience personally rewarding [37]. The increase in participants' sense of empowerment (score of 4.20, as mentioned under

Table 3. Beta Testing Results.

TAM construct	Item assessed	Mean		Difference
		Alpha	Beta	
Perceived usefulness	Awareness of carbon footprint (Visualization/ report)	4.16	4.23	0.07
	Awareness of climate initiatives (Challenges/ Donation/ Volunteer)	4.11	4.18	0.07
	Awareness of causes and consequences (Shop's theoretical information)	4.08	4.10	0.02
	Willingness to take initiatives (Challenges)	–	4.18	–
	Motivation to learn by Challenges' rewards	–	4.10	–
	Motivation by leader board	–	3.85	–
Perceived ease of use	Challenges	3.77	4.35	0.58
	Donation/ volunteer centre	3.77	4.20	0.43
	Acquisition and comprehension of theoretical information	3.89	4.20	0.31
	Ease of understandability of carbon footprint	3.95	4.25	0.30
Attitude towards using	Shop	4.05	4.23	0.18
	Challenges	4.19	4.25	0.06
	Future usage of game	4.05	4.10	0.05
	Volunteer Centre	4.19	4.20	0.01
Intention to use	Donation/Volunteer Centre	**3.41**	**3.90**	**0.49**
	Climate Guardians (the game)	3.89	4.10	0.21
	Shop	**3.89**	**4.03**	**0.14**
	Reward-based Challenges	4.08	4.20	0.12
	Carbon footprint visualizations	–	4.20	–

Beta Testing's General Feedback) suggests that gamification has increased user's belief and confidence in their ability to take climate change mitigation initiatives (autonomy).

Social Relatedness. Despite increased willingness and empowerment to act, participants rated the leader board's effectiveness moderately (3.85, in Table 3, TAM Construct: Perceived Usefulness), indicating that they would prefer not to compete, when it comes to climate change. *Social relatedness* (the need for connection) through actual contributions in action or donations is more meaningful. For instance, participants have rated an average score of 4.18 (Table 3) for their willingness to engage in real-life climate

change mitigation initiatives after learning from the mini games. Thus, while gamification increases willingness to act through the SDT framework, enhancing the social aspects of the game, e.g. allowing collaborative challenges, can further foster a sense of collective purpose, engagement and motivation to act [36].

4.3.3 Analysis of Research Question 3

Will gamification, e-commerce, and the integration of a carbon footprint calculator contribute to actions that would reduce carbon footprints?

The integration of gamification and a carbon footprint calculator can foster accountability by providing a measurable outcome of user's in-game choices, with participants noting an increased awareness of their carbon footprint after interacting with it (average score of 4.23, see Table 3). This indicates that real-time feedback (increase/decrease in carbon footprint calculation) can positively influence user perception and understanding of their environmental impact, encouraging users to make more informed lifestyle changes. This finding is consistent with previous research by [40], which shows that awareness of one's carbon footprint is strongly correlated with increased carbon-reduction practices, as individuals are more inclined to adopt sustainable behaviours when they are aware of the issues and their implications.

This can also be explained by [41]'s study, which identifies that digital platform that offered environmental feedback, such as carbon footprint calculations can influence users to adjust their climate-related habits. [41] stated that their findings aligned with previous research, indicating that feedback could lead individuals to change their consumption, which could reduce emissions linked to consumption by 23%.

Additionally, the *donation* feature with achievements as motivators, provides a direct method for players to support climate action, where donations would go to organizations focused on carbon footprint reduction, such as those running recycling campaigns. The beta testing results showed an average intention to use score of 3.90 (Table 3). While this indicates a neutral-to-positive willingness to donate, it suggests that users had moderate motivation to support environmental causes. Although intention by itself does not ensure action, the inclusion of the donation mechanism appears promising, especially if future developments combined it with more social incentives or community-based objectives.

5 Conclusion

In conclusion, this research project demonstrates the potential of integrating mini games with gamification into e-commerce as an effective strategy to raise climate change awareness and reduce individual carbon footprints. By incorporating gamified elements such as rewards, badges, and a carbon footprint calculator, the app has successfully engaged users, promoting sustainable behaviors.

The findings have highlighted the positive impact of the app's carbon footprint calculator and interactive game simulations, which have notably increased participants' awareness of climate change and motivated them to engage in climate mitigation efforts. However, the use of leaderboards have not significantly increased motivation, suggesting that users prefer collaboration instead of competition, to address climate change. While

leader boards create a sense of competition, participants might not have experienced a collaborative social environment to drive motivation. To address this, [36] suggests implementing social forums for users to share their experiences, connect with friends, and monitor peer's progress, to provide social support and accountability that sustains their motivation. [37] also suggests activities that would emphasize the significance of the player's involvement for the team activity, which may be communicated through an engaging narrative (a gamification element) in the game.

Thus, this study has confirmed the three hypotheses, that integrating e-commerce with a climate change game mobile app can drive actions that would reduce carbon footprints. Furthermore, knowledge enlightens the sense of purpose and drives action more than gamification elements themselves. These highlight the importance of design thinking grounded in more holistic understanding and design based on Game Learning Theory [10]-Krath et al.'s [36] goals, immediate feedback, continuous reinforcements and Self-Determination Theory's [34] competence, social-relatedness and autonomy. However, as the current study does not assess their long-term behaviour, future research can employ longitudinal studies to measure long-term adoption. We also hope to contribute to the United Nations Collaborative Program on Reducing Emissions from Deforestation and Forest Degradation in Developing Countries, albeit in an urban context.

Ultimately, this study concludes that the combination of gamification in e-commerce and educational games, along with tools, e.g., carbon footprint calculators, can contribute to reductions in carbon footprints. Above all, the transition from a simple calculator to a visualized carbon footprint report, the change of real-life challenges into interactive mini games, highlights the importance of direct contextualization and immediate relevance. Thus, gamification emerges as a viable alternative compared to more costly technologies, e.g., AR and VR.

6 Limitations and Future Work

The study recognizes several limitations. Firstly, the user base was relatively small (N = 37 for alpha testing, N = 40 for beta testing) and skewed towards younger demographics, which limits generalizability of the findings. Hence, the observed climate change initiatives might not extend to other age groups unless they were frequent e-commerce users. Additionally, the evaluation was conducted over a short period, measuring intention rather than actual behavioral change. While the data suggested an increase in climate-related awareness and short-term willingness to act, long-term behavioral intention remains uncertain. As such, future research should include longitudinal studies to assess whether users would maintain reduced consumption and altered purchasing habits over time.

Furthermore, due to time and resource constraints, the carbon footprint calculator relied on generalized emission factors from Europe and Malaysia, which may not accurately reflect individual user behaviors in Malaysia. Future work could improve the accuracy of the carbon footprint calculator by incorporating more localized data and personalized activity tracking. Moreover, employing game engines and Procedural Content Generation techniques could enhance the game's interactivity. Additional features, such as social and collaborative elements like team challenges, could be incorporated

to emphasize the collective impact on climate change. Social media APIs could also be integrated to allow users to share their achievements or eco-friendly behaviors, providing social proof to motivate others to join in.

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