Human-Centered Design and Evaluation of a Gamified 2D Animation with Visual Effects for Environmental Awareness

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Abstract:
This study examines a human-centered approach to design and evaluate a gamified two dimensional (2D) animation enhanced with dynamic visual effects (VFX) for promoting environmental awareness. Framed within the domain of Human–Computer Interaction (HCI), the research explores how visual design, narrative structure, and embedded gamification elements influence user engagement, usability, and perceived behavioural intention. The development process followed the Multimedia Development Life Cycle (MDLC), integrating core serious game elements such as goal framing, narrative conflict, feedback cues, and reward visualisation into the animated storyline. A mixed-method evaluation was conducted with participants from diverse age groups, including adolescents and adults, combining post-exposure quantitative surveys and qualitative feedback to assess four dimensions: knowledge acquisition, technical readiness and media familiarity, visual and design appeal, and perceived impact. The results indicate strong perceived performance in technical readiness (M = 4.32) and visual engagement (M = 3.94), alongside increased awareness of littering issues (M = 3.87). However, perceived motivation to take direct anti-littering action remained moderate (M = 3.60), highlighting the challenge of translating awareness into behavioural intention. Overall, the findings suggest that gamified 2D animation with dynamic VFX can serve as an effective human-centered communication tool for environmental awareness by fostering engagement and perceived attitudinal influence. The results are interpreted as self-reported perceived impact rather than direct measurement of behavioural change, indicating the need for future studies employing longitudinal or experimental designs to examine actual behavioural outcomes.
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Keywords: Human-computer interaction; Human-centered design; Gamification; Serious games; 2D animation

1. INTRODUCTION

Littering is a widespread environmental problem that imposes significant ecological, social, and economic costs. It contributes to pollution, degrades ecosystems, threatens biodiversity, and diminishes the aesthetic appeal of public spaces. The economic burden of litter management, including clean-up operations and environmental restoration, is substantial (1). Despite public awareness campaigns, traditional approaches often fail to produce lasting behavioural change, particularly among younger audiences who are less responsive to static media (2).

Gamification and serious games have emerged as powerful tools for influencing behaviour by combining entertainment with purposeful educational content (3). By embedding game mechanics into non-game contexts, gamification can enhance engagement, motivation, and learning outcomes (4). Within environmental education, serious games have been successfully applied to promote awareness of issues such as recycling, biodiversity conservation, and sustainable consumption (5, 6).

In this study, gamification is applied primarily at a cognitive and narrative level rather than through direct user interaction. Although the medium is a non-interactive 2D animation, gamification elements such as goal framing, narrative conflict, feedback cues, and reward visualisation are embedded to encourage mental simulation, emotional engagement, and moral alignment with the environmental message. This approach aligns with serious game principles, where behavioural influence is achieved through narrative immersion and perceived consequences rather than explicit gameplay mechanics. As such, the animation is positioned as a gamified serious game intervention designed to influence attitudes and behavioural intention through visual storytelling.

The *Stop Littering with Dynamic VFX* project was conceived as a gamified 2D animation designed within a serious game framework. While the medium is animation, the design integrates core serious game elements—goal setting, feedback loops, and achievement cues—into its narrative and visual design. The storyline follows Roy, a protagonist committed to environmental stewardship, confronting Jack, a litterer, in a sequence that combines dramatic conflict with

educational messaging. This narrative is enhanced by dynamic VFX to create visual emphasis and increase immersion, making key scenes more memorable (7). Gamification elements are subtly embedded in the animation: Goals - The protagonist's mission to stop littering establishes a clear objective for the viewer to align with; Feedback - Visual and auditory cues reinforce correct actions (e.g., disposing waste in bins); and Challenge: The conflict sequence introduces tension and resolution, akin to a game level progression.

These features aim to encourage viewers to mentally participate in the narrative, increasing the likelihood of internalising the message and translating it into real-world behaviour. The project's objectives include 1) To investigate the environmental impacts of littering and the potential of gamified media to influence related behaviours; 2) To design a 2D animation incorporating gamification and VFX to deliver an engaging anti-littering message; and 3) To evaluate the animation's effectiveness in enhancing engagement, message retention, and behavioural intention. The scope focuses on awareness and behavioural intention rather than direct policy change or physical clean-up efforts. Distribution is optimised for online platforms such as YouTube, Instagram, and TikTok to reach a wide and diverse audience.

The significance of this work lies in its intersection between environmental education, multimedia design, and serious game methodologies. By integrating VFX into a gamified animation narrative, the project demonstrates how entertainment-driven media can be strategically adapted for educational purposes. Prior studies indicate that serious games incorporating immersive storytelling can produce stronger behavioural shifts compared to traditional awareness campaigns (8, 9). The *Stop Littering* project seeks to build on these findings, offering both a proof of concept and an evaluation framework for future initiatives targeting environmental issues.

In summary, this paper positions *Stop Littering with Dynamic VFX* not merely as an animation, but as a gamified serious game intervention. By merging educational objectives with compelling visuals and narrative, it aims to inspire pro-environmental behaviour, particularly in younger demographics, and contribute to the broader discourse on the application of serious games for societal impact.

1.1 Serious Games and Gamification in Education

Serious games are designed with purposes beyond entertainment, often aimed at education, training, or behaviour modification (1). They incorporate game mechanics—such as goals, feedback systems, rewards, and challenges—into scenarios intended to promote learning and engagement. Gamification, on the other hand, applies these mechanics to non-game contexts, enhancing user motivation and participation (2). Studies have shown that gamification in educational settings can improve knowledge retention, foster problem-solving skills, and encourage positive behaviour change (3, 4). In environmental education, serious games and gamification have been used to raise awareness and encourage sustainable practices. For example, *Eco*, an online simulation game, challenges players to build a civilisation while managing environmental resources sustainably, leading to increased awareness and action among its players (5). The success of such projects underscores the potential for game-based interventions to address environmental challenges in an engaging and interactive way (6). The game demonstrates how resource management, feedback systems, and long-term consequences can be used to promote environmental awareness and responsible decision-making. Figure 1 illustrates the ECO online simulation game as a reference example of serious game implementation for pro-environmental education.

Figure 1. ECO – Online simulation game.

1.2 Animation as a Medium for Serious Games

Animation provides a versatile platform for serious games because it allows designers to create compelling, imaginative environments without the constraints of live-action production (7). 2D animation offers a balance of visual appeal, cost-efficiency, and expressive storytelling capabilities. The use of animation in serious games can simplify complex ideas, visualise abstract concepts, and create strong emotional connections with audiences (8). According to Mayer's Cognitive Theory of Multimedia Learning, combining verbal and visual channels enhances comprehension and retention by engaging multiple cognitive pathways (9). When paired with gamification, animation becomes a powerful medium for delivering targeted educational content, maintaining attention, and encouraging active participation (10).

1.3 Gamification for Pro-Environmental Behaviour

Gamified approaches have proven effective in promoting environmentally friendly behaviours, such as recycling, energy conservation, and waste reduction (11, 12). By integrating elements like progress tracking, point systems, and visual feedback, gamification creates a sense of achievement that motivates repeated engagement. Guillen-Hanson et al. (13) found that gamified environmental campaigns could increase long-term behavioural intention compared to traditional campaigns.

Littering, as a subset of environmental issues, is particularly suitable for gamified intervention because it involves simple, repeatable actions (e.g., using a trash bin) that can be easily reinforced through positive feedback loops (14). The design of *Stop Littering with Dynamic VFX* leverages this principle by rewarding correct waste disposal through visual effects and narrative outcomes, simulating the reinforcement mechanisms of serious games.

1.4 The Role of Visual Effects (VFX) in Engagement

VFX enhances the visual appeal and emotional impact of animated content, making it more memorable and immersive (15). In serious games, VFX can be used to highlight key learning moments, simulate real-world phenomena, or provide feedback on user actions (16). For example, glowing effects or particle animations can signal a successful action, reinforcing correct behaviour through immediate and visually stimulating cues (17).

The application of VFX in *Stop Littering with Dynamic VFX* serves both aesthetic and pedagogical purposes. It emphasises the environmental message by drawing attention to key scenes and actions, increasing the likelihood that viewers will remember and internalise the desired behaviours. A researcher suggested that VFX-enhanced educational content results in higher engagement levels and better knowledge retention compared to plain animation (18).

1.5 Narrative and Behaviour Change

Narratives are central to both animation and serious games, providing context and emotional resonance that can influence attitudes and behaviours (19). A well-structured story with relatable characters allows audiences to empathise with protagonists, thereby making the educational message more impactful (20).

The *Stop Littering* project uses a conflict-resolution structure: the protagonist (Roy) confronts the antagonist (Jack) over littering behaviour, leading to a resolution that reinforces the anti-littering message. This mirrors the "challenge and resolution" format common in serious games, where players are motivated to overcome obstacles to achieve a meaningful goal (21).

Research indicates that emotional engagement through narrative significantly increases the likelihood of behavioural change, especially when the story concludes with a positive and achievable outcome (22). By combining this with gamification elements, the project aligns with best practices for designing persuasive and educational media.

1.6 Multimedia Development Life Cycle (MDLC) in Gamified Animation Projects

The Multimedia Development Life Cycle (MDLC) provides a structured framework for creating multimedia products, including serious games and gamified animations. Its phases—concept, design, material collection, assembly, testing, and distribution—ensure that creative and technical elements are integrated effectively.

For the *Stop Littering* project, the MDLC framework ensured that gamification and VFX elements were incorporated seamlessly into the animation's narrative and visual style. Testing and evaluation phases included gathering audience feedback to refine the design, ensuring that the final product met both engagement and educational objectives.

The literature consistently supports the integration of gamification, animation, and VFX in educational media as an effective strategy for engagement and behaviour change. Serious game frameworks provide the structural foundation for these interventions, while animation and VFX enhance their emotional and aesthetic appeal. The *Stop Littering with Dynamic VFX* project embodies this integration, offering a replicable model for future initiatives aimed at fostering pro-environmental behaviours.

2. METHODOLOGY

The methodology for this study is designed to align with serious game development and evaluation best practices, following a structured process to ensure that both the creative and pedagogical objectives are met. The project adopts the Multimedia Development Life Cycle (MDLC) framework, adapted for the integration of gamification and serious game elements into a 2D animated production. The target audience primarily focused on younger viewers; however, the evaluation sample included participants from multiple age groups to capture broader audience perceptions.

2.1 Research Design

This study adopts a mixed-method evaluation approach combining post-exposure quantitative surveys and qualitative feedback. The quantitative component captures participants' self-reported perceptions of awareness, engagement, and behavioural intention after viewing the animation, while the qualitative component gathers open-ended feedback regarding narrative clarity, visual appeal, and message effectiveness. Although the study design was informed by pre–post evaluation principles, this paper reports post-exposure findings and interprets the results as perceived impact rather than statistically measured behavioural change.

A total of n = 25 participants participated in the evaluation. The gender distribution comprised 20 males (80%) and 5 females (20%). Participants represented a mixed age demographic, including adolescents and adults, reflecting a broader audience exposure to the animation. Ethical considerations were observed throughout the study. Participation was voluntary, and all responses were collected anonymously. For participants below the age of 18, parental consent and participant assent were obtained prior to data collection. No personally identifiable information was recorded, and all procedures complied with institutional ethical guidelines for research involving human participants, including minors.

2.2 Development Framework

The project follows six MDLC phases. Concept – Defining project goals, identifying the primary target audience as younger viewers, and establishing the environmental theme (anti-littering) in line with pro-environmental behaviour change objectives; Design – Creating storyboards and scripts integrating gamification elements (goals, challenges, feedback loops, and rewards) into the narrative; Material Collection – Producing digital assets including hand-drawn 2D frames, background illustrations, and VFX sequences. Tools used include *FlipaClip* for animation frames and *Adobe Premiere Pro* for compositing; Assembly – Integrating all visual, audio, and gamified interaction cues into a cohesive animation sequence; Testing – Conducting pilot testing with a sample audience to identify technical errors, narrative clarity issues, and engagement gaps; Distribution – Publishing the animation to online platforms (YouTube, Instagram, TikTok) for public access and further audience feedback.

2.3 Gamification and Serious Game Elements

Gamification refers to the integration of game-like mechanics and dynamics into non-game contexts to increase engagement, motivation, and user interaction. In educational media, including environmental awareness campaigns, gamification has been shown to enhance user participation and improve knowledge retention by providing clear goals, feedback mechanisms, and rewards. Serious games, on the other hand, are designed with primary purposes beyond entertainment, such as education, training, and behavioral change. In the context of this project, both gamification and serious game principles were incorporated into the 2D animation to reinforce the message on littering prevention and environmental responsibility.

The main objective of applying gamification elements in this project was to encourage viewers to actively process and internalize the anti-littering message, rather than passively consuming the content. Several core gamification components were considered: Clear Goals – The animation established a central mission: to protect the environment by preventing littering. This goal was consistently reinforced throughout the storyline; Challenges and Progression – The narrative incorporated problem-solving scenarios where characters addressed littering issues in different settings, simulating real-life decision-making situations; Feedback and Consequences – Visual cues and dynamic VFX were used to provide immediate feedback. Positive actions, such as proper waste disposal, triggered rewarding visual effects, while negative actions were met with contrasting visuals to signal undesirable outcomes; Rewards and Positive Reinforcement – In a gamified approach, rewards such as character acknowledgment or environmental improvement visuals served to reinforce desired behavior; Story-driven Motivation – The storyline created an emotional connection with the audience, making the environmental cause more relatable and memorable.

The integration of these gamification elements within the serious game framework allowed the animation to go beyond simple information delivery. By embedding these mechanics into the plot and visual effects, the animation encouraged active cognitive engagement, promoted better message retention, and increased the likelihood of influencing viewers' attitudes. This approach aligns with prior research indicating that gamification can enhance educational media effectiveness by making learning experiences more interactive, immersive, and personally meaningful.

3. DEVELOPMENT

The authors proposed "Stop Littering" animation is designed as a short, impactful 2D animated video incorporating dynamic visual effects (VFX) to deliver an anti-littering message. The following analysis outlines the core specifications, narrative structure, visual resources, technical requirements, and animation techniques necessary for development.

3.1 Project Specifications

The animation is optimized to be under four (4) minutes, balancing message delivery with audience attention span. A target output of 30 frames per second (fps) will be adopted to ensure smooth visual playback, while the creation process will maintain a minimum of 24 fps for efficient production without sacrificing visual quality.

3.2 Storyline Development

The narrative follows a clear cause–effect–resolution sequence to maximize engagement and message retention. Introduction - A bird is seen scavenging leftover trash discarded carelessly. The main character, Roy, notices the litter and approaches the scene; Conflict - Roy, angered by the sight, confronts Jack—the litterer. Jack dismisses Roy's remarks and attempts to leave; Escalation - Roy pursues Jack across the city, culminating in a physical altercation designed to represent the fight against irresponsible behavior; Resolution- Roy forces Jack to dispose of the trash correctly, concluding with a direct anti-littering message to viewers.

3.3 Data and Techniques

Data and Source Analysis involved Background Design - Key environments include a modern urban cityscape, rooftop settings, and open land areas. These settings visually contextualize the message and provide contrast between polluted and clean spaces; and Character Design - Characters are designed with expressive facial and body animations to convey emotional responses—ranging from annoyance to determination—to enhance audience connection.

Needs Assessment involved Animation Style - 2D hand-drawn animation with stylized backgrounds and fluid character movements, augmented by VFX to emphasize environmental elements and action sequences; Technical Requirements - Development will utilize dedicated drawing tools for frame-by-frame animation, video editing software for scene compilation and sound integration, and hardware capable of handling high-resolution asset rendering.

While Techniques for Production involved Hand-Drawn Animation - *Keyframe Animation* for major poses and actions, with in-between frames to ensure smooth motion, *Limited Animation* in non-critical segments to optimize production time, and *Classical Animation Principles* (e.g., squash and stretch) for expressiveness. VFX Integration included environmental effects such as smoke, debris, and weather patterns to reinforce environmental storytelling, scene transitions enhanced with subtle motion graphics, and special effects for key moments (e.g., impact bursts during action scenes).

By clearly defining these specifications and aligning them with the target audience's preferences, the "Stop Littering" animation will be positioned to maximize both educational impact and viewer engagement. To ensure narrative coherence and effective integration of gamification elements, a storyboard was developed during the design phase to visualise scene progression, character actions, and key visual effects. The storyboard served as a planning tool to align narrative flow, visual emphasis, and educational objectives before full animation production. Figure 2 presents selected storyboard frames illustrating the main narrative structure of the project.

4. TESTING AND ANALYSIS

Testing is an essential phase to validate both the technical performance and the educational impact of the "Stop Littering" 2D animation. This process ensured the final output met its intended objectives, including smooth animation playback, effective message delivery, and positive influence on audience attitudes toward littering.
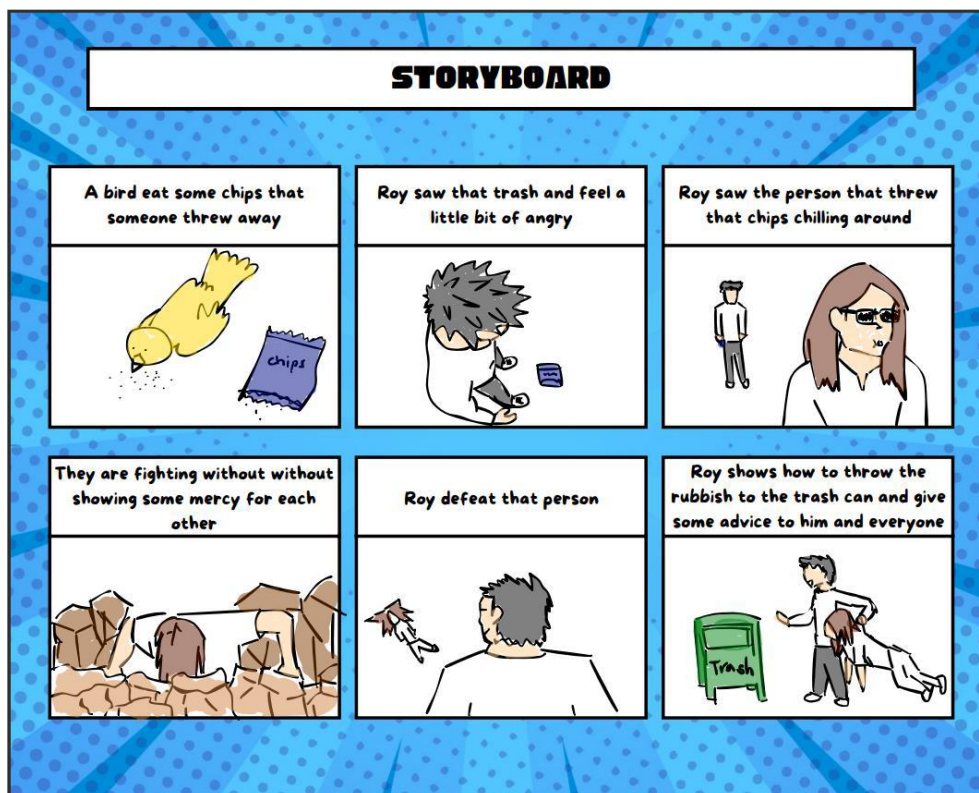

Figure 2. Storyboard for the project.

4.1 Test Plan and Users

The testing involved both internal and external evaluation. Internal testing focused on identifying and resolving technical issues such as frame rate drops, unsynchronized audio, or incorrect rendering. External testing gathered user feedback from the intended audience demographic, comprising primarily young viewers alongside a smaller segment of adult participants to represent a broader audience spectrum. Testing was conducted in a controlled environment using standard playback devices to simulate realistic viewing conditions.

4.2 Test Methodology

Three main approaches were applied included Observation Testing – Real-time audience reactions were noted during playback; Structured Questionnaire – Participants completed Likert-scale questions (1 = Strongly Disagree, 5 = Strongly Agree) grouped into knowledge, technical quality, visual design, and impact; and Expert Review – An academic expert in animation and multimedia evaluated the production quality, narrative delivery, and educational value.

4.3 Test Results

The questionnaire items were grouped into four constructs: knowledge, technical readiness and media familiarity, visual and design appeal, and perceived impact. The technical readiness construction was intended to assess participants' baseline familiarity with digital devices and media consumption, ensuring that technical limitations did not confound the evaluation of the animation itself. The internal consistency of the questionnaire was assessed using Cronbach's Alpha. All constructs demonstrated acceptable reliability, with alpha values exceeding the recommended threshold of 0.70, indicating satisfactory internal consistency for exploratory evaluation.

The evaluation results of the "Stop Littering" animation were analysed across multiple constructs to capture participants' perceptions and responses comprehensively. The knowledge construct, which examines awareness and understanding of littering issues, is summarised in Table 1. Participants' technical readiness and media familiarity, assessed to ensure that technology usage did not influence the evaluation outcomes, are presented in Table 2. The visual and design appeal of the animation, including visual style, character design, and background integration, is reported in Table 3. The perceived impact of the animation in terms of awareness raising, motivation, and recommendation likelihood is shown in Table 4. In addition, the conceptual mapping between key design elements and targeted behavioural constructs is provided in Table 5. For the quantitative results, The Likert-scale analysis showed consistently positive scores across all dimensions.

Table 1. Knowledge mean and standard deviation.

Item	Mean	Std. Deviation
How aware are you of the littering problem in your community?	3.88	0.588
To what extent do you think littering is a significant issue?	4.04	0.599
How familiar are you with the consequences of littering on the environment?	4.00	0.566
To what extent have you been involved in anti-littering activities?	3.12	0.993
How important is it to address the littering issue in your opinion?	4.32	0.615
Overall Mean	3.87	0.672

Table 2. Technical readiness and media familiarity mean and standard deviation.

Item	Mean	Std. Deviation
How often do you use computers or smartphones?	4.60	0.632
How familiar are you with different types of videos (e.g., animations, documentaries, commercials)?	4.16	0.674
How often do you watch videos on online platforms?	4.32	0.677
How comfortable are you with using technology?	4.40	0.693
How important are visuals and sound effects for you when watching videos?	4.12	0.652
Overall Mean	4.32	0.666

Table 3. Visual and design mean and standard deviation.

Item	Mean	Std. Deviation
How engaging was the animation's visual style?	4.12	0.711
How interesting were the characters in the animation?	4.00	0.632
How well did the background scenes complement the animation?	3.56	0.758
How effectively did the animation use colors to convey its message?	3.92	0.688
Overall, how visually appealing was the animation?	4.12	0.712
Overall Mean	3.94	0.700

Table 4. Impact mean and standard deviation.

Item	Mean	Std. Deviation
To what extent did the animation raise your awareness about the littering problem?	3.72	0.774
How motivated do you feel to take action against littering after watching the animation?	3.60	0.800
Did the animation change your perspective on littering?	3.80	0.632
How likely are you to recommend this animation to others?	4.24	0.585
To what extent do you think the animation achieved its goal of promoting a clean environment?	3.84	0.543
Overall Mean	3.84	0.667

- Knowledge: Participants demonstrated a clear understanding of the anti-littering message, with most able to recall key points about environmental impact.
- Technical Quality: Playback was smooth at 30 fps, with no major glitches reported; some noted that certain VFX scenes could be further refined for clarity.
- Visual & Design Appeal: The hand-drawn art style, expressive character animations, and dynamic VFX received strong positive feedback.
- Impact: A majority expressed that the animation motivated them to adopt proper waste disposal habits, indicating effective behavioral influence.

This mapping illustrates how specific design elements were intentionally aligned with behavioural constructs to support environmental message internalisation through narrative engagement.

Table 5. Mapping design elements to behavioural constructs.

Design Element	Behavioural Construct
VFX feedback	Attitude reinforcement
Narrative conflict and resolution	Norm internalisation
Reward visualisation	Intention strengthening

For the qualitative results, open-ended feedback emphasized the animation's engaging storyline and effective integration of action sequences to maintain interest. Some younger participants requested additional characters or extended runtime to further explore the theme. Several viewers praised the fight scene as a creative way to capture attention while reinforcing the message. The expert reviewer highlighted the balance between entertainment and education, noting the storyline's coherence and the clarity of the environmental message. Minor improvements were suggested, such as optimizing certain sound effect transitions and ensuring all VFX elements support rather than distract from the narrative.

4.4 Analysis

The evaluation results highlight four key aspects of the "Stop Littering" animation: knowledge enhancement, technical quality, visual and design appeal, and overall impact.

4.4.1 Knowledge

Participants demonstrated a moderate to high level of awareness regarding littering issues after viewing the animation. As shown in Table 1, participants reported a relatively high level of awareness about littering (M = 3.88) and recognised its significance (M = 4.04). The highest score (M = 4.32) reflected strong agreement on the importance of addressing the issue, aligning with findings by Abdullah et al. (12), who reported that clear messaging in environmental media Significantly increases perceived urgency. However, involvement in anti-littering activities remained low (M = 3.12), a trend also observed in Lee and Chen (18), where knowledge gains did not necessarily result in increased environmental participation. This indicates that while the animation successfully informed audiences, additional behavioural triggers may be required to convert awareness into active engagement.

4.4.2 Technical Quality

The technical aspect scored the highest overall mean (M = 4.32), showing that participants found the animation smooth, accessible, and technically competent. Frequent usage of digital devices (M = 4.60) and comfort with technology (M = 4.40), likely contributed to this positive perception.

4.4.3 Visual and Design Appeal

Visual engagement scored positively, with the animation's style (M = 4.12) and overall appeal (M = 4.12) being well-received. The lowest rating (M = 3.56) was for background scene integration, indicating a potential improvement area to enhance immersion.

4.4.4 Impact

The impact scores were moderate to high, with the highest mean (M = 4.24) for likelihood of recommending the animation, showing strong word-of-mouth potential. However, motivation to take direct action against littering scored lower (M = 3.60), indicating that while the animation changes perception, more persuasive elements may be needed to drive behavior change.

4.4.5 Overall Conclusion

The results indicate that the "Stop Littering" animation is successful in raising awareness, delivering technical quality, and providing an engaging visual experience. The animation is well-positioned as an educational tool, but future improvements could focus on increasing viewer motivation to take direct environmental action and refining certain visual elements, particularly background integration.

5. CONCLUSION

This study set out to design, develop, and evaluate a 2D animation with dynamic visual effects aimed at raising awareness about the negative impacts of littering and encouraging positive environmental behavior. The animation served both as an educational tool and as a medium for creative storytelling, with the goal of enhancing viewers' knowledge, technical engagement, visual appreciation, and motivation to act against littering. Guided by the project objectives, the research involved a comprehensive production pipeline—from conceptualization and scriptwriting to animation design, VFX integration, and post-production—followed by an evaluation phase involving target audience feedback.

This project successfully developed and evaluated a 2D animation with dynamic visual effects aimed at raising awareness about littering and promoting responsible waste management. The evaluation results indicated that the animation performed well in four key areas: knowledge, technical quality, visual and design appeal, and overall impact. Knowledge scores showed that participants were aware of the littering problem (M = 3.88) and its significance (M = 4.04), with the highest agreement on the importance of addressing the issue (M = 4.32). Technically, the animation received the highest overall mean (M = 4.32), supported by high comfort levels with technology (M = 4.40) and frequent device use (M = 4.60). Visually, the animation's style (M = 4.12) and overall appeal (M = 4.12) were well-received, though background integration scored lower (M = 3.56), suggesting room for improvement. In terms of impact, participants were likely to recommend the animation (M = 4.24), but motivation to take direct anti-littering action was relatively lower (M = 3.60), reflecting the common challenge of converting awareness into behavior change. Overall, the animation proved effective as an educational tool, delivering clear messages through strong technical execution and engaging visuals. Future improvements could focus on enhancing visual cohesion and incorporating more persuasive elements to strengthen its influence on real-world environmental action. While the findings demonstrate strong perceived engagement and awareness, further investigation using controlled experimental designs is required to validate long-term behavioural effects.

This study has several limitations. First, the absence of a formal pre-test restricts causal inference, and findings are interpreted as perceived impact rather than direct behavioural change. Second, the use of convenience sampling limits the generalisability of the findings. Future studies may employ experimental or longitudinal designs to examine actual behavioural outcomes and sustained impact. Although the animation was designed primarily for younger audiences, the evaluation included participants from a wider age range. Future studies may focus on age-specific analysis to better understand differential impacts across demographic groups.

AUTHORSHIP CONTRIBUTION STATEMENT

Hamzah Asyrani: conceptualization, methodology, animation design, data analysis, writing – original draft. A.Z. Labra: data collection, validation, writing – review and editing. Abdullah Bade: visual effects consultation, technical validation. Iznora Aini Zolkifly: supervision, methodology review, final manuscript approval.

DATA AVAILABILITY

The data supporting the findings of this study are not publicly available due to privacy and ethical considerations involving human participants but are available from the corresponding author upon reasonable request.

DECLARATION OF COMPETING INTEREST

The authors declare that there are no competing interests.

DECLARATION OF GENERATIVE AI

The authors declare that generative AI tools were used to assist in language refinement and formatting of the manuscript. The scientific content, data analysis, interpretation of results, and conclusions were entirely generated and verified by the authors.

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