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Design and Development of Character and Environment Assets for an Environmental Pollution Educational Platformer Game

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Abstract: This study aims to develop pixel art visual assets for Beat-A-Pollute, an educational platformer game designed to support junior high school learning on environmental pollution. The research employed the Multimedia Development Life Cycle (MDLC), consisting of Concept, Design, Material Collecting, Assembly, Testing, and Distribution stages. The developed assets included characters, environmental backgrounds, items, user interfaces, quizzes, and intro and outro animations representing water, air, and soil pollution. Testing consisted of internal alpha testing and beta testing involving 42 seventh-grade students from SMP Putra Bangsa who were learning environmental pollution. Beta testing used a five-point Likert-scale questionnaire to evaluate the visual clarity, readability, consistency, attractiveness, and integration of the assets with the learning content. The results showed that all assets were suitable during alpha testing. In the beta testing, the overall mean score was 4.3977 with an overall index of 88.38%, categorized as very good. The assessment items obtained indices ranging from 81.43% to 94.76%, while the item-level standard deviations ranged from 0.70051 to 1.15596. These results indicate that the developed pixel art assets were well received by students and were able to support the presentation of environmental pollution learning content through an interactive game environment.

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INTRODUCTION

Environmental pollution is one of the serious challenges faced by younger generations today. This issue is closely related to various environmental and natural resource problems, including air pollution, floods, droughts, landslides, forest fires, biodiversity loss, ozone layer depletion, and global warming. Many of these problems are exacerbated by a lack of environmental awareness and concern, leading to the prediction that environmental pollution will continue to worsen without appropriate educational efforts (Mauliana et al., 2025).

At the junior high school level, environmental education is integrated into Natural Sciences (IPA) subjects. Environmental pollution is included in the curriculum to enable students to analyse the causes of pollution and its impacts on ecosystems (Syafa'ah & Kinanthi, 2023). Learning is not limited to conceptual understanding but also emphasizes the ability to apply knowledge to real-world problems. The Merdeka Curriculum promotes an integrated approach to Natural Sciences learning by combining concepts from physics, chemistry, and biology within thematic contexts.

Natural Sciences learning is expected to develop students' critical, logical, rational, and applicable thinking skills (Maulidiyah et al., 2024).

Based on an interview with a Natural Sciences teacher at Putra Bangsa Junior High School, although environmental pollution is not considered a difficult topic, many students still experience difficulties in understanding the learning content. The problem is not primarily related to the complexity of the material but rather to the delivery methods, which are considered less engaging and insufficiently capable of actively involving students in the learning process. Lecture-based instruction, practical activities, and ice-breaking activities that have been implemented have not yet optimally improved students' understanding. Technology-based learning media, such as videos, applications, and educational games, have also not been utilized optimally, despite students' high enthusiasm for smartphones and their familiarity with digital games. This condition presents an opportunity to develop interactive learning media that corresponds to students' characteristics and interests.

As an approach to addressing these challenges, a platformer game-based learning medium has the potential to support students' motivation and understanding. This study focuses on the development of pixel art visual assets for an educational game with an environmental pollution theme. Attractive, informative, and consistent visual assets play an important role in delivering information in multimedia products because visual representations can help students understand abstract concepts in a more concrete and contextual manner. This is consistent with the study by Simanjuntak et al. (2023), which demonstrated that the quality of game assets contributes to the overall essence and fundamental quality of a game, with asset usability testing obtaining a score of 86.25, categorized as "good." In addition, research on the implementation of Balinese traditional clothing and houses as 2D pixel art game assets demonstrated that appropriate asset design can preserve philosophical meanings and informative values even when presented through a simplified visual style, while also serving as a design reference for multimedia developers (Prestiliano et al., 2020). These studies indicate that visual assets serve not only as aesthetic elements but also as strategic components for conveying educational messages and values. Therefore, this study is designed to produce pixel art assets that are not only visually appealing but also educationally meaningful and relevant to Natural Sciences learning, particularly environmental pollution.

This study aims to describe the design and development process of pixel art assets used as supporting media for environmental pollution learning in an educational platformer game. The development focuses on visual assets consisting of characters, environments, items, user interfaces, and supporting animations, which are designed to represent environmental pollution concepts in a clear, engaging, and comprehensible manner. By producing a structured and contextualized asset package, this study seeks to demonstrate that pixel art assets can function not only as visual elements but also as important components for conveying environmental pollution learning content interactively through educational games. The study is theoretically grounded in environmental literacy, integrated Natural Sciences learning, interactive learning media, and pixel art design principles. The research employs the Multimedia Development Life Cycle (MDLC), which consists of six stages: Concept, Design, Material Collecting, Assembly, Testing, and Distribution (Haris et al., 2024; Ilona & Maulana, 2025)

The resulting assets are expected to provide both practical and academic benefits. Practically, the developed assets can support the development of educational games and facilitate junior high school students' understanding of environmental pollution concepts.

METHODS

The research workflow, as presented in Figure 1, begins with problem identification and the formulation of research objectives. This stage focuses on the need for game-based learning media for environmental pollution and the role of visual assets as primary supporting elements for delivering learning content. The scope of the study is also determined at this stage, specifically focusing on the development of pixel art assets for an educational platformer game. The next stage is a literature review covering environmental pollution concepts, the characteristics of learning media, educational games, and pixel art visual styles. The findings from the literature review serve as the basis for formulating the design requirements from both conceptual and technical perspectives. Conceptually, the assets must clearly and educationally represent different types of environmental pollution. Technically, the assets must accommodate the resolution limitations of pixel art, maintain color consistency, and meet the implementation requirements of a 2D platformer game.

Based on these requirements, the research proceeds to the concept stage, which includes determining the game theme, visual style, characters, environments, and educational elements to be visualized. The concept is then translated into design sketches as preliminary asset designs. These sketches are used to visualize the shapes, proportions, and visual style of the assets before entering the production stage. After the sketches are prepared, the material collecting stage is conducted by gathering visual references, color palettes, and examples of pixel art assets to maintain design consistency. The next stage is assembly, which involves producing character, environment, item, and pixel art animation assets using Aseprite according to the predetermined design concepts and technical requirements.

The completed assets then proceed to the testing stage, which consists of internal alpha testing and beta testing. Alpha testing is conducted internally to evaluate visual suitability, the clarity of material representation, and asset consistency. Beta testing is subsequently conducted to assess the feasibility of the developed assets from the users' perspective. The final stage is distribution, in which the completed research outputs are presented as an asset package that is ready to be integrated into game-based learning media. Overall, this research workflow ensures that the asset development process is conducted systematically by considering both conceptual and technical aspects as the basis for design, resulting in assets that are relevant, consistent, and aligned with the intended learning objectives

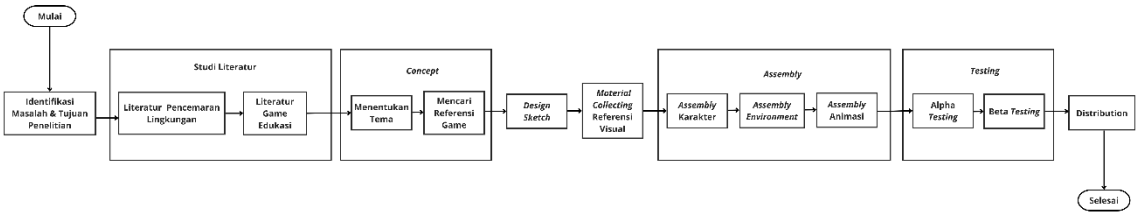


Figure 1. Research Workflow
Source: Author's Documentation

RESULTS & DISCUSSION

A. Game Description

Beat-A-Pollute is an educational platformer game designed to actively engage players in learning about environmental conservation. In the game, players control the main character, Recycle Hero, an environmental hero tasked with cleaning up various forms of pollution that threaten the environment in Indonesia. The game consists of three main levels, each representing a different environmental condition: a polluted river, a city affected by air pollution, and barren land caused

by environmental pollution. Throughout the game, players are required to collect waste and hazardous materials while navigating platforms, avoiding obstacles, and encountering enemies that represent different forms of pollution. These gameplay elements are designed to integrate environmental pollution concepts into the game experience. At the end of each level, players encounter a boss that presents questions related to environmental pollution. The boss challenges combine gameplay progression with educational evaluation, requiring players to demonstrate their understanding of the learning material to proceed.

B. Sketch Design

A sketch is an initial visual design that serves as the foundation for the asset development process in a game. Sketches are created to visualize previously formulated concepts, allowing abstract ideas to be translated into more concrete visual forms (Nurcahyo, 2022). In pixel art asset development, sketches play an important role in determining proportions, basic shapes, visual styles, and composition before the assets are developed into more detailed final versions. The use of sketches also helps establish a more structured development process and minimize potential design errors during production. In this study, sketches were used to establish the initial designs of various assets that would appear in the Beat-A-Pollute game. The sketching process covered several main visual elements, as presented in Figure 2, including the main character, Recycle Hero, enemies representing different types of pollution, and collectible items. These preliminary designs served as visual references for the subsequent pixel art production stage, ensuring that the final assets remained consistent with the established concepts and the educational themes presented in the game.

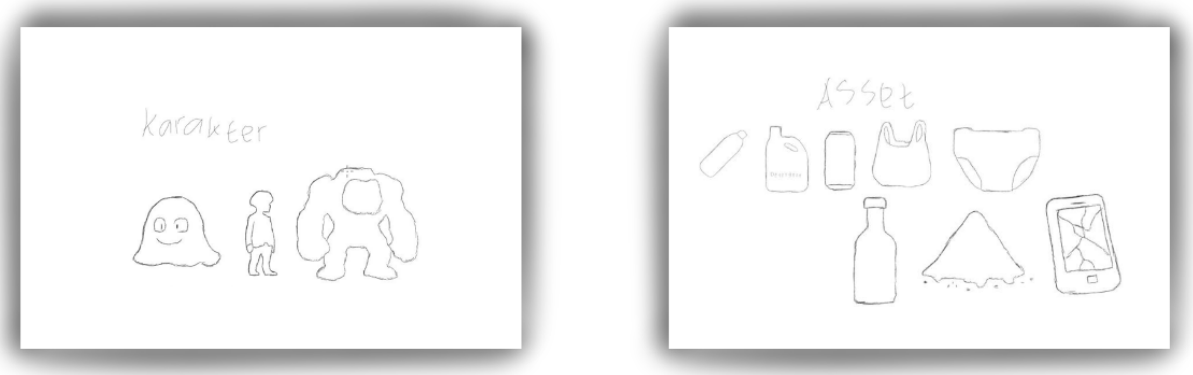


Figure 2. Character & Asset Sketch
Source: Author's Documentation

C. Character Design

Characters are important elements in a game because they serve as the primary medium connecting players with the game world. Through characters, players can understand the objectives of the game, develop emotional engagement, and perform various actions that contribute to the overall gameplay experience (Amani & Yuly, 2019; Prasetya & Rizqi, 2024). In educational games, characters serve not only aesthetic and gameplay functions but also contribute to the delivery of moral messages, educational values, and learning content through their visual representations and behaviors. In this study, character development was conducted to support the storyline and delivery of environmental pollution content in the Beat-A-Pollute game. Three main characters were designed as pixel art assets, as presented in Table 1. The first character is Recycle Hero, a young environmental hero who receives a mission to protect Indonesia from various forms of pollution. The character represents a younger generation with

environmental awareness and serves as the player-controlled character throughout the game. The other two characters are enemies encountered across the three game levels. Slime represents pollution and liquid waste, while Golem is a larger enemy that symbolizes large-scale pollution and environmental degradation. These three characters were designed to strengthen the game narrative while providing an educational and interactive gameplay experience for users.

Table 1. Game Character Sprite sheet.

Name	Spritesheet
Hero Idle	
Hero Walk	
Hero Jump	
Hero Attack	
Slime Idle	
Slime Death	
Golem Idle	
Golem Death	

Source: Author's Documentation

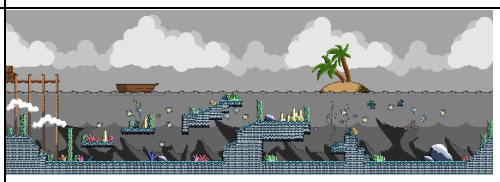
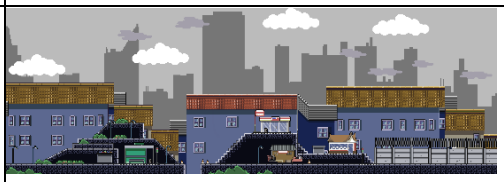
D. Background Design

Backgrounds are visual elements that establish the atmosphere and environmental context of a game. Their function extends beyond enhancing visual appearance, as backgrounds also help players understand the setting, storyline, and conditions of the game world being explored. In platformer games, backgrounds are particularly important because they provide visual depth and strengthen the immersive experience as players move through the game levels. To create a more dynamic and realistic visual experience, this study applies a parallax background technique, in which multiple background layers move at different speeds according to the

movement of the character. Layers positioned farther from the camera move more slowly, creating an illusion of depth and a three-dimensional appearance even though the game is developed in a 2D format (Hartono & Kurniawan, 2022).

In this study, three types of backgrounds were developed based on the environmental pollution themes presented in Beat-A-Pollute: a polluted river, a city affected by air pollution, and barren land caused by environmental degradation, as presented in Table 2. Each background was designed in two conditions, namely polluted and clean versions, to visually represent the transformation of the environment after conservation efforts are carried out. The polluted versions use darker and more gloomy visual tones and include elements such as accumulated waste, water contamination, and smoke or smog representing ecosystem degradation caused by a lack of environmental awareness. In contrast, the clean versions present brighter, healthier, and well-maintained environments, providing a visual representation of the positive outcomes associated with environmentally responsible behavior.

Table 2. Game Background Assets.

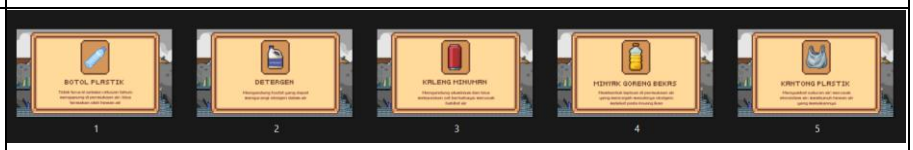
Name	Clean Background	Polluted Background
Water Pollution		
Air Pollution		
Soil Pollution		

Source: Author's Documentation

D. Item Design

Items in a game are objects that can be collected by players to achieve specific objectives within a level. In Beat-A-Pollute, items function not only as gameplay elements but also as educational media that provide players with relevant environmental knowledge. Each item represents a type of waste or source of pollution commonly found in the real world. When players interact with an item, educational information is presented to explain its environmental impact and why the waste needs to be properly managed. Through this mechanism, learning content is delivered interactively within the gameplay experience (Naglé et al., 2021). The items are divided into three levels based on the type of environmental pollution: water pollution, air pollution, and soil pollution. Each item was selected based on common pollution cases in Indonesia to ensure that the learning content remains relevant to environmental conditions encountered by students. The items and corresponding learning materials implemented in each level are presented in Table 3.

Table 3. Items and Learning Materials.

Level	Items	Learning Material
Level 1	Plastic Bottle, Used Oil, Used Can, Chemical Detergent, Plastic Bag	
Level 2	Used Vehicle, Tire Burning, Cigarette, Waste Burning, Factory Smoke	
Level 3	Used Battery, Glass Bottle, Damaged Mobile Phone, Diaper, Cement Residue	

Source: Author's Documentation

E. Quiz Design

Quizzes are an important element of the educational game because they function as an evaluation mechanism to measure players' understanding of environmental pollution concepts acquired throughout the gameplay. In addition to serving as a learning assessment tool, the quiz is integrated into the gameplay mechanics, requiring players to actively understand the learning material to progress through the game (Bintaratih & El-Yunusi, 2024). In Beat-A-Pollute, a quiz is presented at the end of each level, immediately before the player defeats the boss. To defeat the boss, the player must answer three questions related to the type of pollution discussed in the corresponding level, as presented in Table 4. The questions are developed based on the pollution-related items encountered by players during gameplay, allowing the gameplay experience to contribute directly to the learning process. This approach enables the quiz to assess players' understanding while simultaneously reinforcing the environmental pollution concepts introduced throughout each level. The integration of quizzes into boss battles also provides a more interactive approach to learning and connects the assessment process with the game's progression mechanics.

Table 4. Quiz Questions.

Level	Quiz Questions
Level 1	

Level	Quiz Questions
Level 2	
Level 3	

Source: Author's Documentation

F. User Interface Design

User Interface (UI) is the interface that connects players with the game and includes visual elements such as buttons, menus, icons, information panels, and gameplay indicators. UI is designed to help players interact with the game in an easy, clear, and intuitive manner. In educational games, UI plays an important role because it not only facilitates navigation but also ensures that information can be effectively presented and understood by players (Sookkaew et al., 2024; Zheng et al., 2025). In this study, the User Interface was designed to support the gameplay experience of Beat-A-Pollute while maintaining the pixel art visual style, as presented in Figure 3. Several UI elements, including buttons, dialogue panels, and icons, were created specifically for the game to meet its visual and functional requirements. Other elements were obtained from freely licensed assets available online to improve development efficiency. All externally sourced assets were selected by considering their licensing conditions to ensure that the assets could be used legally and were appropriate for academic publication.

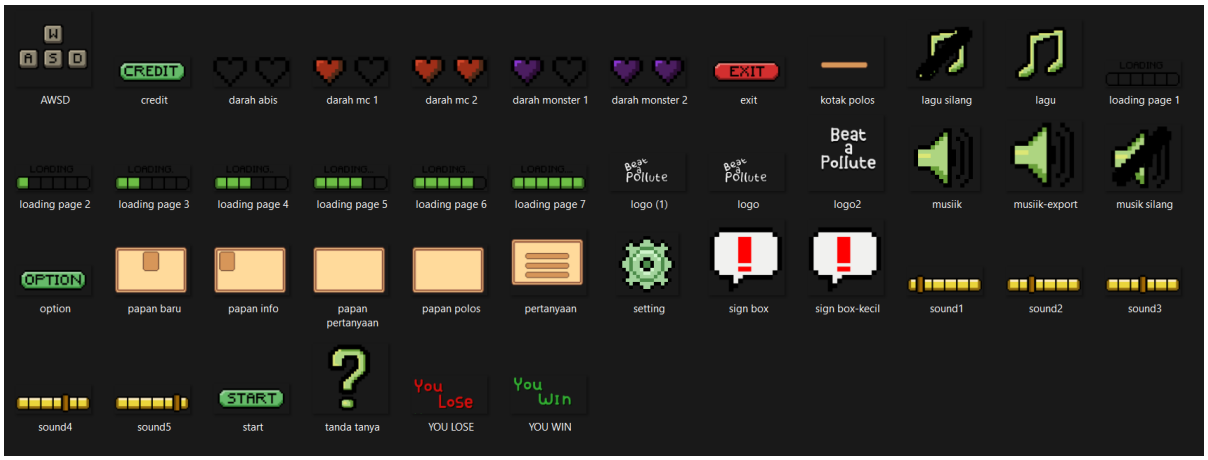


Figure 3. Game User Interface
Source: Author's Documentation

G. Intro and Outro Animation

Intro and outro animations are important elements in educational games because they function as opening and closing sequences that help players understand the context of the learning content presented in each level. Through engaging visualizations, players can more effectively understand educational messages and observe the environmental changes represented in the

game (Marcheta et al., 2024). In Beat-A-Pollute, each level contains an intro animation and an outro animation, as presented in Table 5. The intro animation presents the transformation of the environment from a clean condition into a polluted condition. This transition is used to illustrate various causes of environmental pollution according to the theme of each level, such as waste entering a river, increased vehicle emissions, or waste accumulation on the ground. This approach allows players to understand how human activities can contribute to environmental degradation while providing contextual information before gameplay begins. In contrast, the outro animation presents the transformation of the polluted environment back into a clean condition. This sequence illustrates how environmentally responsible actions can contribute to the restoration of environmental conditions. The outro animation reinforces the positive impact of the actions performed by the player throughout the level while conveying the environmental awareness message intended by the educational game.

Table 5. Intro and Outro Animation List.

Level	Script	Visualization
Intro Level 1	*"Dulu, laut ini biru dan jernih. Tapi sekarang? Warnanya aneh... ada yang hijau, hitam, bahkan coklat. Bau busuk tercium dari jauh, dan busa serta minyak mengambang di permukaan air. Dulu, laut ini biru dan jernih. Tapi sekarang? Warnanya aneh... ada yang hijau, hitam, bahkan coklat. Bau busuk tercium dari jauh, dan busa serta minyak mengambang di permukaan air."*	
Outro Level 1	*"Kamu berhasil membersihkan laut dari sampah dan mengalahkan polusi air! Tapi ingat, menjaga kebersihan air bukan tugas sekali saja. Yuk terus jaga air kita tetap bersih! Mulai dari tidak buang sampah ke sungai atau laut. Hemat air dan matikan keran saat tidak dipakai."*	
Intro Level 2	*"Kabut tebal menggantung di udara, membuat mata perih dan dada sesak. Debu beterbangan di mana-mana, dan asap hitam keluar dari kendaraan dan pabrik. Ini tanda udara kita tercemar parah. Kalau dibiarkan, manusia, hewan, bahkan tumbuhan bisa sakit. Ayo, waktunya bersih-bersih udara! Kumpulkan sumber polusi dan selamatkan kota dari asap berbahaya!"*	
Outro Level 2	*"Kamu berhasil membersihkan udara dari polusi! Tapi misi menjaga udara tetap bersih belum selesai. Yuk mulai dari langkah kecil:* *Jalan kaki, bersepeda, atau naik transportasi umum. Tanam pohon di lingkungan sekitar.* *Jangan bakar sampah sembarangan.* *Dengan udara bersih, hidup jadi lebih sehat dan bumi makin nyaman!"*	

Level	Script	Visualization
Intro Level 3	*"Tanah ini dulu subur dan penuh kehidupan. Tapi sekarang? Tanaman sulit tumbuh, banyak yang layu dan mati. Warnanya aneh, permukaannya keras, dan bau kimia menyengat tercium dari tanah. Tak ada lagi makhluk kecil yang hidup di dalamnya. Sampah berserakan di mana-mana, dan air malah menggenang. Kalau dibiarkan, tanah ini akan mati. Ayo, bersihkan polusi, pulihkan tanah!"*	
Outro Level 3	*"Kamu berhasil membersihkan tanah dari sampah dan polusi! Tapi menjaga tanah tetap subur adalah tugas kita semua. Yuk mulai dengan langkah-langkah sederhana: Pisahkan sampah organik dan anorganik. Gunakan kompos dari sisa dapur. Kurangi plastik, dan tanam pohon. Dengan tanah yang sehat, bumi kita pun akan semakin hijau dan kuat!"*	

Source: Author's Documentation

H. Alpha Testing

Alpha testing is an initial testing stage conducted internally to ensure that the assets intended for use in the game function properly and appear according to the established designs (Ilona & Maulana, 2025; Kho et al., 2018). In this study, alpha testing was conducted to evaluate asset suitability, UI functionality, animation performance, and the integration of educational elements, including learning materials and quizzes. The purpose of alpha testing was to identify potential errors, deficiencies, or inconsistencies at an early stage so that improvements could be implemented more quickly and systematically. The testing results presented in Table 6 show that all evaluated aspects were categorized as "Suitable." This indicates that the developed assets met the basic requirements established for the initial development stage. The test covered the main character, enemies, parallax backgrounds, environmental assets, item assets, user interface, intro and outro animations, and quiz assets.

Table 6. Alpha Testing Results

No.	Tested Asset	Testing Indicator	Result
1	Main Character (Recycle Hero)	Idle, run, and jump sprites function smoothly; proportions are appropriate	Suitable
2	Enemies (Slime & Golem)	Movement animations and visual collision detection function properly	Suitable
3	Parallax Background	All layers are displayed correctly; clean and polluted versions appear according to the level	Suitable
4	Environment Assets	Platforms, obstacles, and decorations are displayed consistently	Suitable
5	Item Assets	Item shapes are clearly recognizable and can trigger the display of learning materials	Suitable
6	User Interface	Icons, buttons, and panels are consistent with the pixel art style	Suitable
7	Intro & Outro Animations	Clean-to-polluted and polluted-to-clean visual transitions function properly	Suitable

No.	Tested Asset	Testing Indicator	Result
8	Quiz Assets	Question panels are displayed clearly and the text is readable	Suitable

Source: Author's Documentation

I. Beta Testing

Beta testing is a testing stage conducted after all assets and game features have been confirmed to meet the requirements established during alpha testing. At this stage, the game is evaluated directly by the intended users to assess the readability of the visual assets, ease of use (usability), and overall visual comfort during gameplay (Ilona & Maulana, 2025; Tanoto et al., 2024). In this study, beta testing involved 42 seventh-grade students from the partner junior high school who were studying environmental pollution. The testing aimed to evaluate the feasibility and effectiveness of the developed visual assets as supporting media for learning, particularly in presenting environmental pollution concepts in a clear and engaging manner.

The evaluation focused on students' responses to the user interface, characters, environmental backgrounds, educational items, animations, and quiz elements integrated into the game. Students completed a questionnaire using a five-point Likert scale to assess visual representation clarity, the ease of understanding icon and button functions, text readability, pixel art style consistency, and the integration of visual assets with the learning content. The results presented in Table 7 show that all assessment aspects obtained indices above 80%, ranging from 81.43% to 94.76%. The overall average index was 88.38%, which falls into the very good category. These results indicate that the visual assets, game interface, and supporting visual elements were well received by the seventh-grade students. The students were able to understand the game interface, read the displayed text, distinguish the visual characteristics of each level, and interact with the game without significant visual confusion. The findings indicate that the developed assets were able to support both the gameplay experience and the delivery of environmental pollution learning content.

Table 7. Beta Testing Results

No.	Assessment Aspect	N	Mean	Std. Deviation	Total Score	Index (%)
1	he game menu at the beginning s easy to understand.	42	4.3810	1.03482	184	87.62%
2	he button is easy to recognize when starting the game.	42	4.0714	1.15596	171	81.43%
3	he button location is easy to find.	42	4.3333	0.92833	182	86.67%
4	he text and colors are easy to read.	42	4.7381	0.70051	199	94.76%
5	he health/life bar is clearly visible.	42	4.2857	0.89131	180	85.71%
6	he pixel art style makes the game visually appealing.	42	4.4524	0.77152	187	89.05%
7	ach level has an attractive environment.	42	4.6429	0.75938	195	92.86%
8	haracter and enemy movements are easy to see.	42	4.3095	0.97501	181	86.19%
9	he quiz interface is clear and easy to understand.	42	4.4762	0.86216	188	89.52%

No.	Assessment Aspect	N	Mean	Std. Deviation	Total Score	Index (%)
10	The overall appearance is easy to see and not confusing.	42	4.5000	0.74080	189	90.00%
Total/Average		42	4.3977	—	1,856	88.38%

Source: Author's Documentation

CONCLUSION

This study resulted in the development of pixel art assets for the Beat-A-Pollute educational platformer game, focusing on characters, environmental backgrounds, items, user interfaces, quizzes, and supporting animations for environmental pollution learning. The development process was conducted using the Multimedia Development Life Cycle (MDLC), covering the Concept, Design, Material Collecting, Assembly, Testing, and Distribution stages. The developed assets were designed to represent water pollution, air pollution, and soil pollution through contextual visual elements and gameplay interactions. Alpha testing showed that all evaluated assets were suitable for integration into the game. Furthermore, beta testing involving 42 seventh-grade students resulted in an overall index of 88.38%, categorized as very good, with individual assessment indices ranging from 81.43% to 94.76%. These findings indicate that the developed visual assets were well received by students and were able to support the presentation of environmental pollution learning content within an interactive game environment. Future research can expand the development by evaluating the effectiveness of the complete Beat-A-Pollute game in improving students' knowledge and environmental awareness through pre-test and post-test measurements. Further studies may also examine the influence of specific visual elements, animations, and game mechanics on learning outcomes and student engagement. In addition, future asset development can explore other visual styles, accessibility considerations, and broader environmental topics to increase the applicability of educational game-based learning media.

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