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Design and Development of the 2D Android-Based Game 'Let's Sort It' Using the Game Development Life Cycle

Diny Anggriani Adnas[1], Melisa[2]
diny.anggriani@uib.ac.id, 2131088.melisa@uib.edu
[1,2]Faculty of Computer Science, Universitas Internasional Batam, Batam, Indonesia

Abstract

This research aims to design and develop a 2D Android-based educational quiz game titled "Let's Sort It", using the Game Development Life Cycle (GDLC) method. The purpose of the game is to help teenagers recognize and classify different types of waste, including organic, inorganic, and hazardous (B3) waste, in an engaging and interactive way. The research uses a qualitative experimental approach with a Research and Development (R&D) method, incorporating stages such as initiation, pre-production, production, testing, and release. Data were collected through questionnaires using a Likert scale distributed to teenage users after gameplay. The results show that the majority of users responded positively to the game's interface design, gameplay experience, and educational content. Users found the game enjoyable and informative, contributing to a better understanding of proper waste classification. In conclusion, "Let's Sort It" is a feasible and effective educational tool that combines entertainment with environmental awareness, and it holds potential for further development and integration into environmental education programs.

Keywords:

Educational Game, Game Development Life Cycle (GDLC), Android, Waste management

Introduction

Waste management issues have become increasingly crucial in various regions, especially in Indonesia. The volume of waste that continues to increase each year not only affects environmental cleanliness but also public health and ecosystem balance. Waste is an environmental problem that negatively impacts human health and ecosystems if not managed properly. According to data from Sustainable Waste Indonesia, Indonesia produces more than 65 million tons of waste annually. That amount, only a small portion is properly managed (Simamora, E., & Junuudhizbulloh, A. J., 2023). One of the main causes is the low public awareness of the importance of sorting and processing waste according to its type: organic, inorganic, and hazardous and toxic materials (B3).

Organic waste can cause air pollution and foul odors if not properly processed, while inorganic waste such as plastic and metal is difficult to decompose and can pollute soil and water (Ardhita, F. & Usiono, 2025). In addition, B3 waste, which contains hazardous substances such as mercury and lead, can cause serious health problems. Pollution caused by waste also contributes to various diseases, such as dengue fever, coughing, and respiratory infections due to toxic gases from waste burning (Lestari, I., & Ramdhayani, E., 2022). Sorting waste into organic, inorganic, and B3 categories allows for easier recycling and processing.

Organic waste, for example, can be processed into compost that enriches the soil, while inorganic waste like plastic can be recycled into other useful products, and B3 waste such as used batteries, which are flammable, must be disposed of separately with special treatment. By using this method, the amount of waste ending up in landfills (TPA) can be reduced, thereby minimizing environmental pollution risks. One of the main causes of this problem is

the lack of awareness and understanding among the public—especially the younger generation—about the importance of sorting waste from an early age. Awareness of the importance of waste sorting should be instilled from a young age so that this habit becomes embedded in daily life (Pujowati et al., 2024).

Therefore, the author developed the game "Let's Sort It" with the aim of helping teenagers learn about different types of waste in an engaging and accessible way. The use of the Game Development Life Cycle (GDLC) in the development of this educational game ensures that the creation process is carried out in a structured manner. GDLC consists of several stages: initiation, pre-production, production, testing, beta, and launch. Using GDLC in the development of educational games can help optimize learning outcomes. With technological advancement, people increasingly rely on mobile phones in their daily lives. The Android platform was chosen as the development medium because of its wide user reach and high accessibility (Deda et al., 2023). By leveraging this potential, the development of an Android-based educational game can become an easily accessible learning tool. Through this educational game, the author hopes that teenagers can learn about waste types and sorting methods in a fun way. It is expected that the game can help children understand proper waste sorting in their everyday lives.

Literature Review

A. Literature Review

During the writing of this research, the author used references from various previous studies as sources of information to build a scientific theoretical foundation for the research title.

A study conducted by Ulfa, E. N., Metandi, F., & Nyura, Y. (2024) featured a game titled "Trashpocalypse." In the development of the Trashpocalypse game, the Game Development Life Cycle (GDLC) method was used, consisting of six stages: initiation, pre-production, production, alpha testing, beta testing, and release version. This method supports a structured and systematic game development process. The results and conclusions of the Trashpocalypse development showed that the use of Unity as a development tool was highly effective, efficient, and flexible in supporting the required features. With the application of GDLC, the development process proceeded in a structured manner and produced a bug-free game after testing, particularly through black box testing during the alpha and beta phases. Moreover, the game succeeded in delivering a fun and unique gameplay experience while conveying a strong educational message about the importance of keeping the environment clean from waste. In conclusion, Unity significantly supported the development of this game, and the application of GDLC helped ensure the quality and success of the development process overall.

Another study by Wahyudinata, A., & Dirgantara, H. B. (2020) titled "Development of a 2D Educational Game for Recycling Waste Sorting Based on Android" also used the Game Development Life Cycle (GDLC) method. The results of this educational game development showed that all game functions worked well based on the conducted black box testing. Furthermore, the test results proved that the game successfully motivated players to sort recyclable waste themselves, with 76.2% of respondents feeling encouraged after playing. The conclusion of this study is that the game can effectively motivate and improve public understanding of the importance of waste sorting.

Another study by Gusti Purwanto, A., & Windriyani, P. (2022) developed a game titled "PilahPilih." The game was developed using the Game Development Life Cycle (GDLC) method, which involved several stages, including initiation, pre-production, production, testing, beta, and release. This GDLC approach guided a systematic development process and ensured that the game functioned well while effectively educating players about waste sorting. The development results of PilahPilih showed that the game successfully enhanced players' understanding of different waste types, with 94.1% of 17 respondents becoming more knowledgeable after playing. In addition, 88.2% of participants felt motivated to sort waste independently after playing. The study concluded that PilahPilih was effective as a learning medium for waste sorting, demonstrating potential to raise awareness and encourage behavioral change regarding proper waste management through an interactive and engaging gameplay experience.

Another study by Fernando et al. (2024) designed a game titled "Pilah Sampah." The game development used the Game Development Life Cycle (GDLC) method. The study results indicated that Pilah Sampah was effective in improving students' understanding of proper waste sorting. Specifically, the percentage of students confident in their

ability to sort waste correctly increased from 76.67% before using the game to 93.33% afterward. During beta testing involving 30 students, there was a 16.66% increase in confidence levels, demonstrating the game's positive impact. The study concluded that Pilah Sampah performed well in all tested functions and effectively improved students' knowledge and confidence in waste sorting. It was recommended that the game be further enhanced by adding levels and offline access features for improved usability.

Another study by Sidik et al. (2024) developed a game titled "Recycle Ranger." This educational game was developed using the Game Development Life Cycle (GDLC) method. The results showed that the developed game successfully achieved its educational objectives. Testing confirmed that all features and mechanisms functioned properly, and the interactions produced the expected outcomes, with all responses rated as "Successful." In addition, user testing showed a significant improvement in children's ability to distinguish between different types of waste after playing the game. The game was also effective in increasing environmental motivation and awareness among players. The study concluded that the game effectively helped children learn about waste classification, environmental impact, and encouraged environmentally friendly behavior. The game was visually appealing, interactive, and served as a powerful educational medium that can contribute positively to environmental education and sustainable waste management initiatives.

B. Theoretical Basis

1. Game Development Life Cycle

The Game Development Life Cycle (GDLC) is a framework used in game development, encompassing the stages of conceptualization, pre-production, production, testing, release, and maintenance and updates. Conceptualization focuses on the game's ideas, genre, and mechanics, while pre-production involves technical planning. The production stage includes programming, creation of visual and audio assets, and implementation of game features, which are then tested to ensure stability and quality. After the game is released to the public through various platforms, the maintenance stage is conducted to fix bugs and add updates to enhance player experience.

2. Waste Sorting

Waste sorting is the process of categorizing waste based on its type to facilitate better waste management. According to Law No. 18 of 2008 on Waste Management, waste is classified into three main types: organic waste, inorganic waste, and hazardous and toxic waste (B3). Organic waste consists of materials that decompose naturally, such as food scraps and leaves. Inorganic waste includes materials that are difficult to decompose but often recyclable, such as plastic, paper, and metal. Meanwhile, B3 waste refers to hazardous materials like used batteries or electronic waste, which require special handling to avoid negative impacts on the environment and human health.

3. Game-Based Learning

Game-based learning supports active learning by providing accessible simulation environments. Games can represent complex situations that are difficult to explain in traditional contexts, making it easier for players to understand certain concepts or skills. For example, in the context of waste sorting, educational games can provide sorting simulations that closely resemble real-life situations, allowing players to learn by trying and experimenting without real-world risks. Game-based learning appears to be a useful tool for educators and parents seeking to encourage positive development in children.

4. Motivation

Motivation in educational games can also be explained through Self-Determination Theory (SDT), which states that human motivation is driven by three basic psychological needs. First, autonomy, where games allow players the freedom to make decisions and explore various possibilities. Second, competence, where games offer challenges that match players' abilities, giving a sense of accomplishment when tasks are completed. Third, relatedness, where games create a sense of social connection, especially in contexts involving cooperation or competition among players.

5. Android

Android is a Linux-based operating system specifically designed for mobile devices such as smartphones and tablets. It was developed by Google and has become one of the most popular platforms for mobile application

development, including educational games. Android provides various tools and frameworks that enable developers to create interactive applications with engaging interfaces. In this study, Android was chosen as the platform because the majority of teenagers in Indonesia use Android-based devices, making the educational game more widely accessible.

Research Methods

This research uses a research design flow consisting of several interrelated stages, namely:

1. Problem Identification
   In the first stage, the problem was identified: the low level of understanding among children regarding waste sorting. Based on this problem identification, the main objective of the research is to increase awareness and understanding among adolescents about waste sorting through an interactive educational game.
2. Literature Review
   This stage aims to explore theories related to educational games, waste sorting, and the characteristics of adolescents. The literature review was conducted to obtain theoretical foundations for designing an enjoyable educational game suited to the target age group.
3. Game System Design
   Based on the literature review, the game design stage was carried out by designing gameplay elements, such as game flow, characters, and interaction mechanisms. The game system design also includes determining the appropriate level of difficulty to match adolescents' understanding.
4. Game System Development
   In this stage, the game was developed based on the previously designed concepts. The game developer implemented the planned features, such as the user interface, interactions, and educational content on waste sorting.
5. Analysis and Testing
   After the game was developed, it was tested with a group of adolescents. This testing aimed to assess how well the game was received by the participants and to what extent they understood waste sorting after playing the game.
6. Evaluation
   The evaluation stage was conducted to assess the outcomes of the "Let's Sort It" educational game. The evaluation was carried out using questionnaires, observations, and brief interviews with the participants to measure changes in their understanding of waste sorting after playing the game.

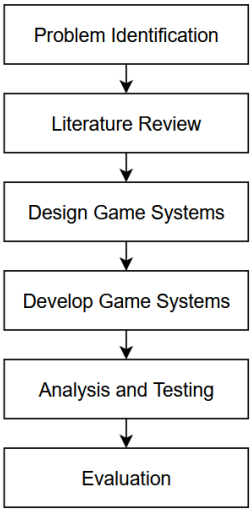


Figure 1. Research Design Flow

Game Development Life Cycle (GDLC) is a series of stages used in the process of developing a game, from planning to release. These stages include initiation, where the core idea and objectives of the game are defined; pre-production, which focuses on design and prototyping; production, the stage where game elements such as graphics, audio, and programming are developed; post-production, which involves testing, bug fixing, and polishing; and finally, distribution and maintenance after the game is released. By following the GDLC, developers can ensure that the game produced is of high quality, aligns with the target market, and is ready to compete in the industry.

1. Initiation
   The initial stage of game development where the author defines the core idea and concept. At this stage, the goals of the game, its genre, and game mechanics are identified.
2. Pre-Production
   The planning phase where the initial game concept is further developed into a more detailed design. An early prototype is created to test the game mechanics before proceeding to full production.
3. Production
   This is the stage where all assets designed in the previous phase are implemented. During this phase, programming is conducted to integrate assets and source code.
4. Testing
   Next, the author tests the game to ensure its quality and that the system functions as intended. Bugs that may not have been previously identified are detected and corrected. The goal is to ensure that the game runs smoothly and to prevent any errors during gameplay.
5. Beta
   After testing is completed and necessary fixes are made, the game is distributed to the target users for research purposes. The game is given to children to play individually.
7. Release
   In the release stage, after the game has been fully developed and tested during the beta phase, it is ready to be officially launched.

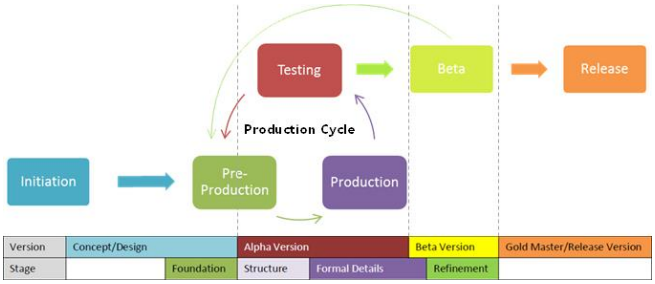


Figure 2. Game Development Life Cycle

Results and Discussion

1. Initiation
   At this stage, *Let's Sort It* is designed as an educational quiz-based game that teaches players about sorting waste into three categories: Organic, Inorganic, and B3 (Hazardous and Toxic Materials). Players are given questions in the form of waste images, and they must select the correct category for each image. Players earn points for choosing the correct category, while no points are awarded for incorrect choices. Players must complete the questions within a specified time limit. The game ends when the time runs out, displaying the total points earned by the player.
2. Pre-Production
   In the pre-production stage, the developer plans the game flow and visualizes the ideas.
   a. Storyboard

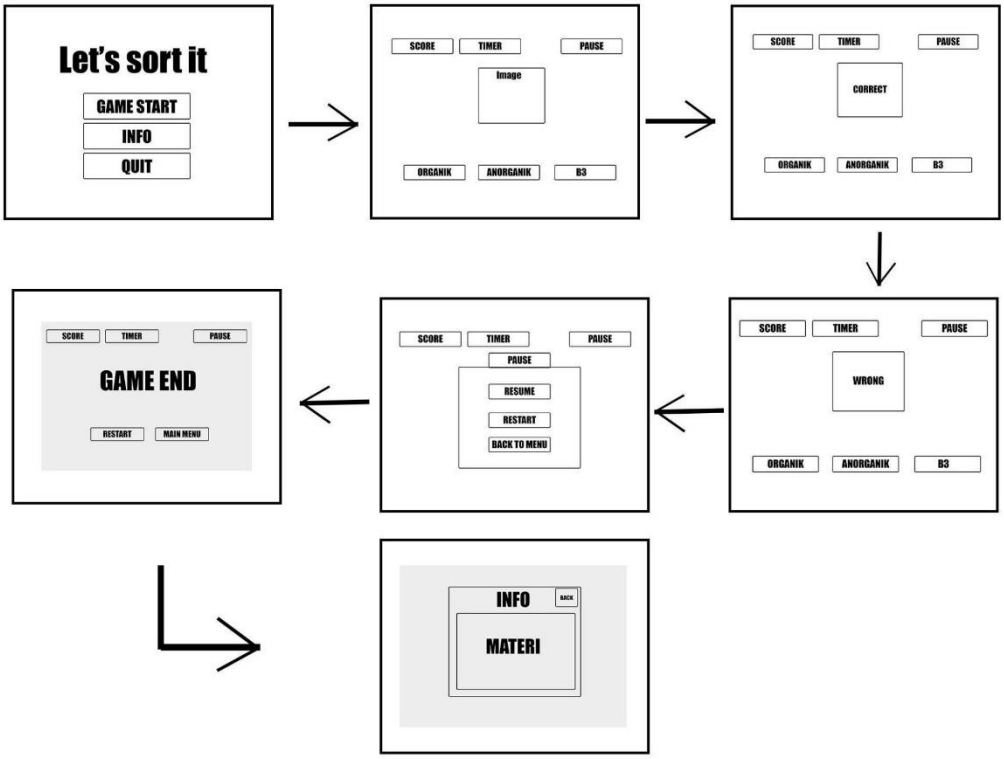


Figure 3. Storyboard

b. Use Case Diagaram

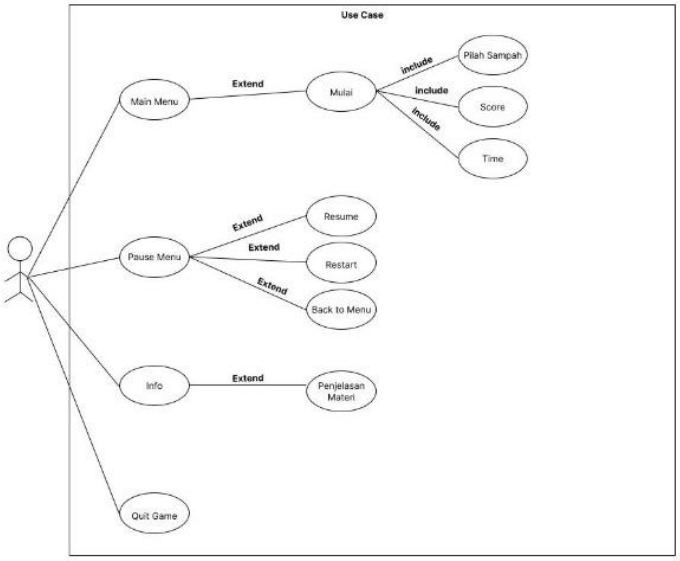


Figure 4. Use Case Diagram

c. Flowchart

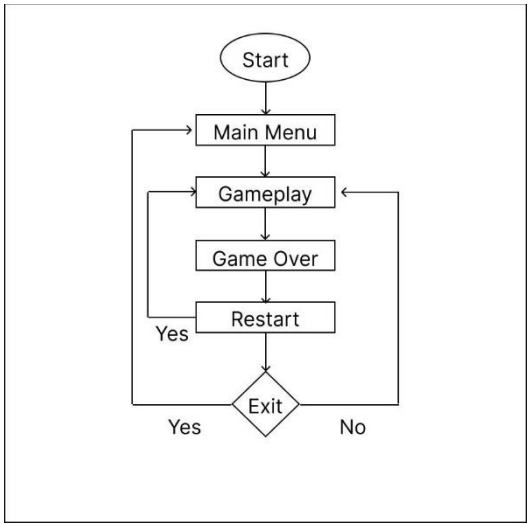


Figure 5. Flowchart

d. Activity Diagram

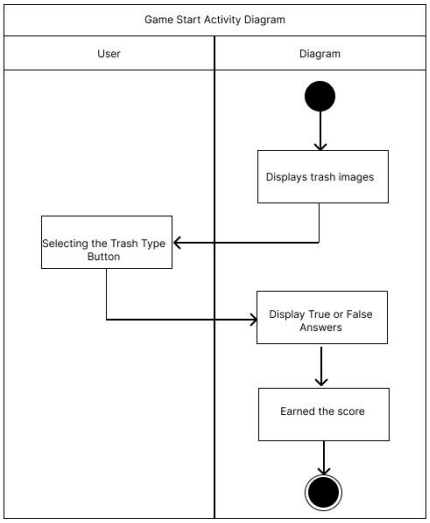


Figure 6. Game Start Activity Diagram

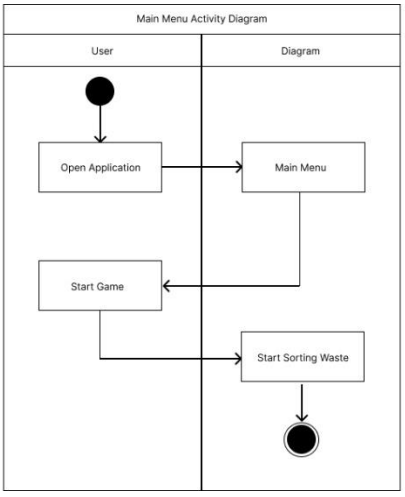


Figure 7. Main Menu Activity Diagram

3. Production

In the Production stage, all the necessary assets are created and integrated. The developer creates assets using Adobe Photoshop, codes, and builds the game using Unity as the game engine. The implementation of the game logic flow is done through programming using the C# language.

a. Game Asset Creation

In the production stage, the visual and audio assets to be used in the game are created and gathered according to the previously prepared design plan. Visual assets, including waste icons, interactive buttons, and backgrounds, are created using Adobe Photoshop.

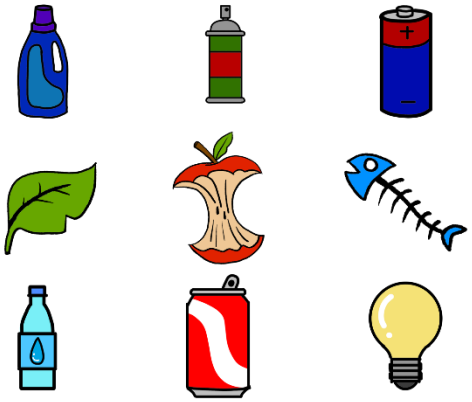


Figure 8. Waste

The interaction buttons used by players to perform commands in the game, such as starting the game, selecting answers, viewing scores, or exiting the game, are designed with bright colors, clear icons, and are touch-responsive to make them easy to use and attractive, especially for adolescents. Meanwhile, the natural environment background serves to create an atmosphere that supports the educational theme of the waste sorting game.

Figure 9. Buttons

Figure 10. Background

Figure 11. Background

b. Game Interface Design

The Main Menu display in the educational game *Let's Sort It* is designed with a simple and user-friendly interface to ensure it is easily understood by adolescents. On this main screen, players are greeted with the game title at the top and a nature-themed background that supports the game's educational theme of waste sorting. In the center of the screen, there are three main buttons: Game Start, Info, and Quit Game, each designed with different colors to distinguish their functions.

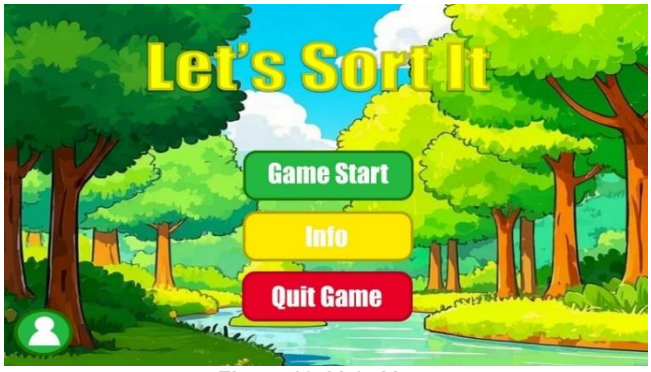


Figure 12. Main Menu

Figure 13. GamePlay

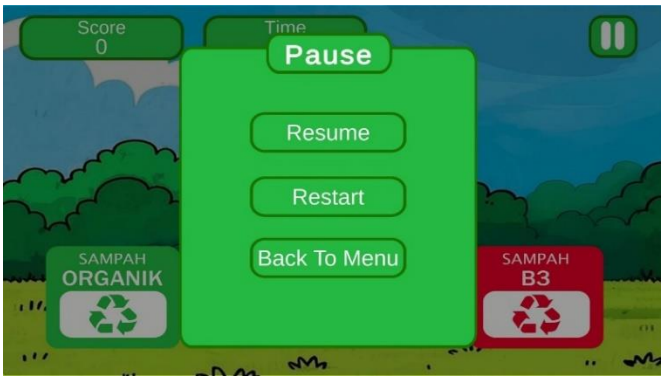


Figure 13. Pause Menu

Figure 14. Game End

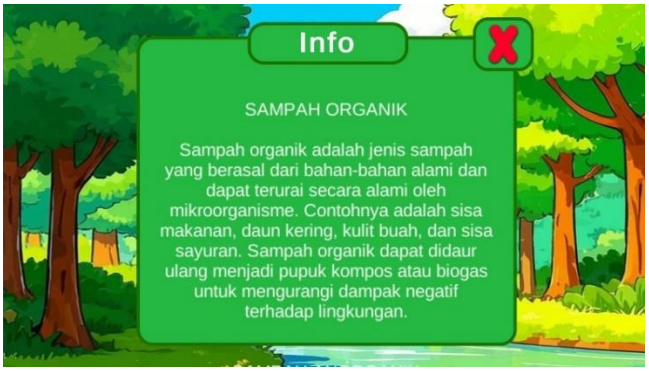


Figure 15. Info

Figure 16. Correct Answer

Figure 17. Wrong Answer

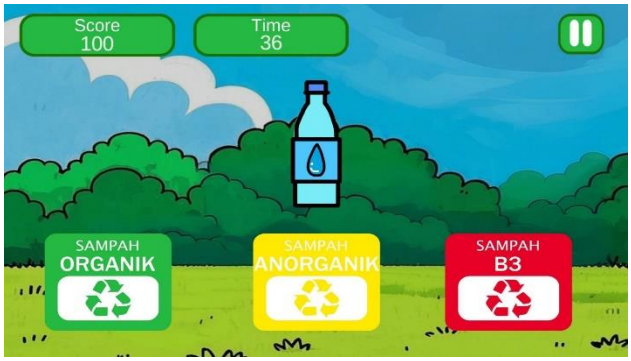
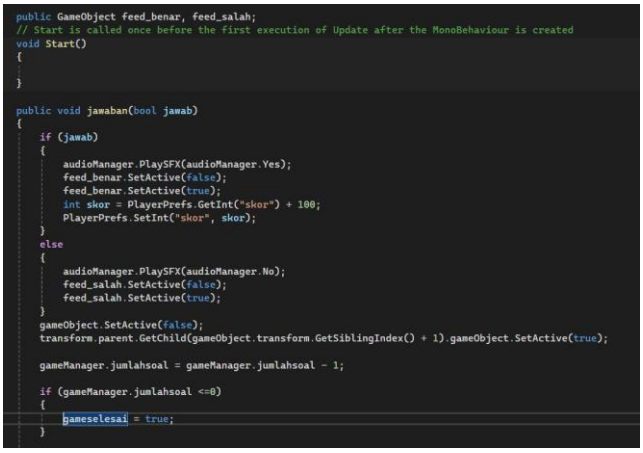


Figure 18. Score and Timer

c. Game System Development

The programming language used in the development of the game "Let's Sort It" is C#, which is the primary language for game development using the Unity Engine. The use of C# allows the developer to write scripts that control game logic, user interactions, quiz mechanisms, and the navigation system between interfaces.



```
public GameObject feed_benar, feed_salah;
// Start is called once before the first execution of Update after the MonoBehaviour is created
void Start()
{

}

public void jawaban(bool jawab)
{
    if (jawab)
    {
        audioManager.PlaySFX(audioManager.Yes);
        feed_benar.SetActive(false);
        feed_benar.SetActive(true);
        int skor = PlayerPrefs.GetInt("skor") + 100;
        PlayerPrefs.SetInt("skor", skor);
    }
    else
    {
        audioManager.PlaySFX(audioManager.No);
        feed_salah.SetActive(false);
        feed_salah.SetActive(true);
    }
    gameObject.SetActive(false);
    transform.parent.GetChild(gameObject.transform.GetSiblingIndex() + 1).gameObject.SetActive(true);

    gameManager.jumlahsoal = gameManager.jumlahsoal - 1;

    if (gameManager.jumlahsoal <=0)
    {
        gameselesai = true;
    }
```

Figure 19. Source code

4. Testing

Game testing used the Black Box testing method, which focuses on testing the application's interface functions and workflow to ensure they produce the expected results.

Table 1. Black Box Testing

Test Case	Expectation	Error	Result
Open Application	The application opens and displays the Main Menu.	-	Success
Start Game Button	The game will start	-	Success
Info Button	Displays a page about material details	Explanatory text does not appear	Success
Quit Game Buttone	The game application will be closed	-	Success
Pause Button	The game will pause and display the Pause Menu.	Game does not pause when Pause Menu is displayed	Success
Organic Waste Button	Shows correct pop up if the answer is correct and gets points and shows wrong pop up if the answer is wrong	-	Success
Inorganic Waste Button	Shows correct pop up if the answer is correct and gets points and shows wrong pop up if the answer is wrong	-	Success
B3 Waste Button	Shows correct pop up if the answer is correct and gets points and shows wrong pop up if the answer is wrong	-	Success

Score	Points earned if the answer is correct	-	Success
Time	Time will run when the game starts and will display game over when time runs out.	Game over display does not appear when time has stopped	Success
Resume Button	Continue the game	-	Success
Restart Button	Restart the Game	-	Success
Back to Menu Button	Back to Main Menu	-	Success

5. Beta

The beta stage involved distributing the game via a Google Drive link, allowing children to download and play it on their mobile phones. Feedback was collected, and improvements were made to ensure the game ran smoothly.

6. Release

After undergoing testing and confirming that no errors or bugs were present, the game was then released. This was done by uploading it to Google Drive and Itch.io, and sharing it with potential users. The game could be downloaded after distribution and played on mobile phones.

7. Evaluation

Based on the results of the questionnaire responses conducted before and after playing the educational game "Let's Sort It," there was a significant increase in respondents' knowledge and awareness regarding waste sorting. Before playing the "Let's Sort It" educational game, a total of 30 adolescents participated as respondents. The total score obtained was 777 out of an ideal score of 1200. Therefore, the overall assessment can be calculated in percentage form, with the results as follows.

$$P = \frac{\Sigma x}{\Sigma xi} \times 100\%$$

$$P = \frac{777}{1200} \times 100\%$$

$$P = 64.75\%$$

The results of the questionnaire before playing the game showed a total percentage of 64.75%, indicating that the respondents' level of understanding, experience, and awareness regarding the importance of waste sorting was still moderate. Many respondents were not yet accustomed to sorting waste and could not distinguish between different types of waste such as organic, inorganic, and hazardous and toxic materials (B3). In addition, most of them had never used educational media in the form of a game to learn about this topic.

After playing the educational game "Let's Sort It," a total of 30 adolescents participated as respondents. The total score obtained was 2000 out of an ideal score of 2400. Therefore, the overall assessment can be calculated in percentage form, with the results as follows.

$$P = \frac{\Sigma x}{\Sigma xi} \times 100\%$$

$$P = \frac{1004}{1200} \times 100\%$$

$$P = 83.67\%$$

After playing the educational game, the percentage increased to 83.67%. This result indicates that the "Let's Sort It" educational game successfully enhanced the respondents' understanding significantly. The respondents stated that the game was presented clearly, was easy to understand, enjoyable, and motivated them to sort waste in their daily lives. Furthermore, the respondents found the game's interface and navigation appealing and supportive of more effective learning. This game not only raised awareness but also fostered interest and enthusiasm among the respondents to apply the knowledge they had gained.

Therefore, it can be concluded that this educational game is an effective learning medium to improve adolescents' understanding of waste sorting. The game is highly recommended for further development and implementation in both formal and informal educational settings to encourage environmentally conscious behavior from an early age.

Conclusions

Based on the data analysis from the questionnaires conducted before and after playing the educational game "Let's Sort It," it can be concluded that the game has a positive impact on increasing participants' understanding of waste sorting. This is evident from the increase in understanding percentage, which rose from 64.75% to 83.67%. This improvement indicates that respondents gained a better understanding of the differences between organic, inorganic, and hazardous (B3) waste, as well as the importance of proper waste sorting. The game was also considered helpful in delivering information in a more enjoyable and interactive way compared to conventional learning methods.

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