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INTERACTIVE MOBILE-BASED EDUCATIONAL GAME TO INTRODUCE WASTE SORTING USING MULTIMEDIA DEVELOPMENT LIFE CYCLE METHOD

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Abstract

Increasing public awareness of waste management is an important focus to maintain environmental sustainability. However, the level of understanding about waste sorting is still minimal, especially among children. To overcome this lack of literacy, a technology-based educational game was developed to introduce the concept of waste sorting to children. This research aims to design and develop an interactive and fun educational game application to improve children's understanding of the importance of waste management. Using iterative development techniques, this app is designed to provide a practical learning experience and support forming positive habits from an early age. The application is designed following the stages of the Media Development Life Cycle (MDLC) method. The game media has gone through several tests, namely software functionality tests with 100% results, learning material tests by distributing questionnaires to material experts with an average rating of 90%, tests to learning media experts with an average rating of 93.33%, and tests to potential users with an average rating of 78.57%. The research results are expected to significantly educate the younger generation, especially children, about the importance of maintaining environmental cleanliness through wise waste management. This application is expected to be an innovative learning tool that supports environmental sustainability.

Keywords: Educational Games, Waste Sorting, Android, Construct2

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1. INTRODUCTION

The increase in Indonesia's population has a significant impact on the increase in household waste, reaching 21 million tons per year. Based on data from the Ministry of Environment and Forestry (KLHK), 65.71% of the waste can be managed, while the remaining 34.29% is not managed properly, thereby polluting rivers, seas and land[1]. This problem is further exacerbated by people's behavior that is less concerned about environmental cleanliness. According to the World Health Organization (WHO), waste is defined as anything that is not used, has no economic value, and often requires high handling costs. [2]. Piles of scattered rubbish reflect a lack of responsibility, regardless of the level of education or social status of the community[3]. In Islam, the importance of protecting the environment has been emphasized in the Qur'an, such as in Surah Al-A'raf: 56 which prohibits destroying the earth after it has been repaired[4]. Public awareness of waste management needs to be increased from an early age so that positive habits can be instilled, one of which is through non-formal education such as educational games[5].

Educational games utilize multimedia elements such as text, sound, images, animation, and video to create interactive learning[6]. Learning games are designed to improve users' thinking power, concentration and problem-solving abilities[7]. With an interesting approach through games, it is hoped that children as the younger generation will be able to better understand the importance of waste management, so that they can play an active role in reducing the accumulation of waste in the future.[8].

Several studies have shown the effectiveness of development methods such as Multimedia Development Life Cycle (MDLC), Software Development Life Cycle (SDLC), and waterfall in producing quality educational games. Trials with

several methods such as the Black-Box method and the SUS scale showed satisfactory results, with an average positive response above 80%. However, further development is still needed to improve features and overcome existing deficiencies[9]. This research aims to develop an educational game to introduce types of waste and the importance of managing it to early childhood children. [10]. Observations were conducted through data collection using questionnaires to measure the degree of understanding regarding types of waste. The author then carried out further observations by analyzing the questionnaire results to assess knowledge about waste types[11].

Unlike previous studies that generally introduced waste types in a static manner or relied on conventional learning approaches, this study adopts a more interactive method through a mobile-based gaming application. The application is developed using the Multimedia Development Life Cycle (MDLC) framework and is designed specifically for early childhood education. By focusing on a fun learning experience with visual and interactive elements, the application is expected to be more effective in enhancing children's understanding and awareness of proper waste management.

From the questionnaire results, it was found that the 'average' category had the largest proportion, accounting for 56.3%, followed by the 'very bad' category at 18.8%, and the 'bad' category at 18.6%. The 'good' category contributed only 6.1%, while the 'very good' category had the smallest proportion at 0.1%. Similarly, the research results indicated that the 'average' category dominated with a proportion of 37.5%, followed by the 'very bad' and 'bad' categories, each contributing 25%. The 'good' category represented 12.5%, while the 'very good' category had no representation at all.Overall, it can be concluded that the 'very good' category has an extremely small proportion or is entirely absent.

To address this issue, the author aims to develop an educational game for the introduction and sorting of waste, created using Construct 2.

2. RESEARCH METHOD

This type of research is Multimedia Development Life Cycle. This research method is considered the most appropriate to answer the problems studied and achieve the research objectives. Game design using MDLC Development Cycle research type[12]. This method consists of six stages: Concept, design, material collecting, assembly, testing, and distribution. Figure 3 explains in full each stage of the MDLC.

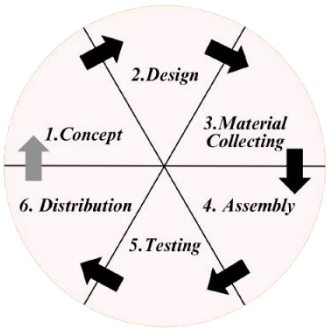

Figure 1. MDLC Research Stages

Each stage is carried out sequentially starting from the concept, namely needs analysis, where observation activities begin by exploring problems that need to be addressed, to formulate technological solutions that will be applied in the development of educational games for introducing waste sorting. Details of the results at each subsequent stage, from design to maintenance, will be explained in the Results and Discussion chapter.

2.1 Concept

At this stage, a needs analysis was conducted to understand the target users and the objectives of the educational game being developed. Based on the questionnaire results, data on understanding waste types and sorting waste are summarized in the following charts:

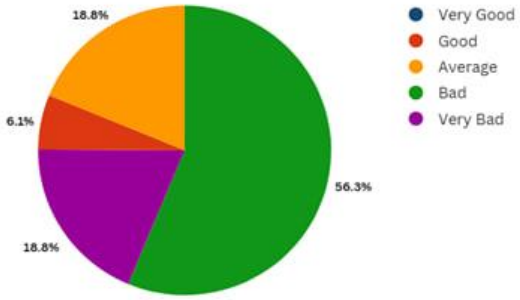

Figure 2. Pre-Research Questionnaire for Understanding Waste Types

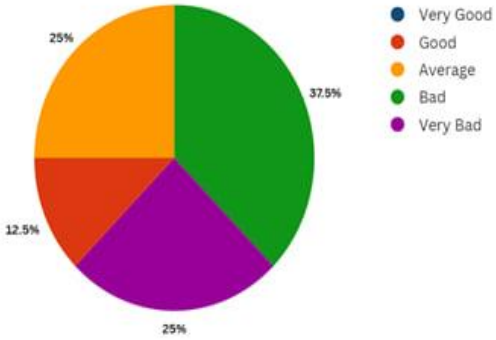

Figure 3. Waste Sorting Research Questionnaire

Figure 2 shows that the majority of respondents fall under the 'average' category in terms of

understanding waste types. Meanwhile, Figure 3 highlights that garbage sorting is predominantly categorized as 'average,' followed by the 'bad' and 'very bad' categories. This indicates the need for more effective educational media to improve both the understanding and sorting abilities regarding waste.

The next step involves defining the purpose of the program and identifying its target audience (audience identification). The goals and intended users of the program significantly influence the design and tone of the multimedia application, as it serves as a reflection of the organization's identity and its aim to deliver impactful information to end users.

At this stage, the researchers focused on determining an appropriate title for the application to ensure it aligns with the needs of students at Muhammadiyah Elementary School:

a. Understanding the purpose and benefits of good and correct educational games in waste sorting using 2D assets. This application is designed for the android platform or mobile phones.
b. The existing content contains an introduction to the types of waste and their sorting.
c. Media content is selected based on the types of waste that exist around the school and are often encountered by students.

In designing the concept of the game to be built, researchers used the Mechanics Dynamic Aesthetics (MDA) framework method[13]. MDA is one of the frameworks that is often used in gamification methods, especially in electronic education systems such as mobile or desktop based game applications. The interactive in this application lies in the buttons that can be used by users so that users can choose the next stage, there is a main menu, Learn, Play, game instructions and exit. The entire explanation of the MDA Framework stages in this research activity can be seen in Table 1. below:

Table 1. Stage of the MDA *Framework*

No	Component Types	Sub Components	Implementation in Games
1	*Mechanics*	Genres and topics	This educational game is for early childhood learning.
2		Purposes	Get to know the types of waste and their management
3		*Platform*	*Mobile Android*
4		App Rating	This game is aimed at children aged 6-12 years.
5		Lavel	Beginner
6		Art Concept	2D game.
7	*Dynamic*	*storyline*	This game provides an introduction to types of waste and waste sorting.
8		Characters	Characters Using 2D trash images
9	*Aesthetic*	*Sensation*	It is hoped that with this application, users will get a pleasant sensation because they can play while learning.
10	*Challenge*		A quiz is provided in the game to evaluate the user's level of understanding after learning through this educational game.

As can be seen in table 1, the MDA Framework method consists of three core components, namely mechanics, dynamics, and aesthetics that complement the conceptual needs of designing a game. This method was chosen by the author because this method is considered to have been widely implemented in modern electronic technology-based education and teaching systems.[8].

2.2 Design

At the design stage, the creation of specifications regarding the program architecture, style, appearance, and material requirements for the design program to be created using the interface design from the application menu display. The software used to design the interface is canva.

The complete design of the menu and features of the Waste Sorting Introduction Game are shown in Table 2. Below:

Table 2. Identifyng Menus in the Game

No	Menu Name	Information
1	*Splash Screen*	This is the opening display for the application.
2	Main Menu	Contains all the menus in this application such as Learn, Play, Play Instructions, and Exit.
3	Learning Menu	Contains explanations of the types of waste in the form of writing and pictures.
4	Play Menu	Contains waste sorting, where the process of putting waste in the trash according to its type is carried out.
5	Instructions page	Contains instructions for sorting waste in this application.

a. *Use Case*

The following is a display of the use case diagram for the waste recognition and sorting game application shown in Figure 4. Below:

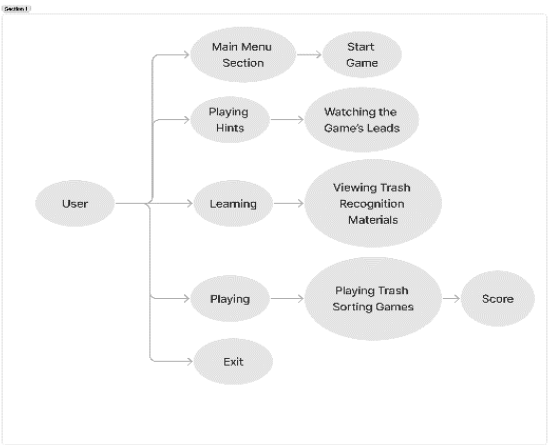

Figure 4. *Use Case Diagram*

b. *Flowchart*

The following is a display of the flowchart in the waste sorting recognition game application shown in Figure 5. Below:

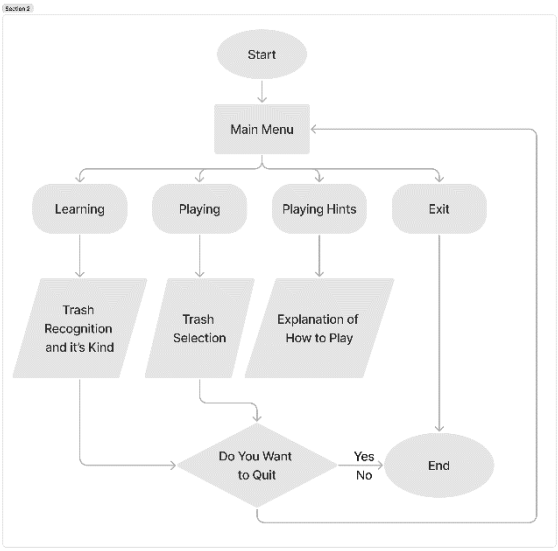

Figure 5. Flowchart of game apps

c. *Mock Up*

The following is an example of the main menu mock-up display in the waste sorting introduction game application as shown in Figure 6. Below:

Figure 6. Mock up for *Main Menu*

2.3 Material Collecting

Collecting materials and making materials to support the process of making educational games in the form of image materials made through supporting applications, sound as additional sound music and materials in the form of books on waste introduction materials and their types. This game material focuses on three types of waste, including:

a. Organic Waste

Organic waste is waste produced from animal and plant materials produced from agricultural, plantation, and fishery activities or from nature. It is biodegradable without any chemical process. This waste can be quickly decomposed through natural processes and its nature can be degraded by microbes[14].

b. Inorganic Waste

Inorganic or non-organic waste is waste produced from non-biological materials, originating from non-renewable natural resources, for example: minerals, petroleum, synthetic products, results of technological processes for managing mining materials and industry. This type of waste is different from organic waste, which is waste that does not decompose quickly so that special steps are taken to accelerate the waste decomposition process. Inorganic waste consists of: metal waste and processed products, plastic waste, paper waste, glass and ceramic waste, detergent waste[15].

c. Hazardous and Toxic Waste

Hazardous and toxic waste is waste produced from hazardous and toxic materials that are flammable, pollute the environment and endanger human health, for example: batteries, light bulbs, paint packaging, vehicle lubricants and so on[16].

2.4 Assembly

In this stage, illustrations are made and applications are created based on mockups and the mechanical dynamic aesthetics (MDA) Framework method which comes from the previous design stage. Starting from the creation of all objects or multimedia materials that are created. This stage includes creating animations, creating game landscapes, creating 2D content, and creating applications[17]. The entire application design process is carried out using construct 2 software. When all the features on the mockup have been completed, then equipped with sound features and evaluation quizzes and settings on the educational game. In this stage of the process, a beta version of the educational game product is produced.

2.5 Testing

After the application is completed, testing is carried out, whether the application is in accordance with what was previously designed or there are still deficiencies and improvements. Identify problems when errors occur in the application. This study uses four tests, namely:

a. Software Functionality Testing

This test is conducted to assess the suitability of the device type and screen size and also the success of the application process and results. This test uses Black Box method[18].

b. Learning Material Test

This test is conducted to check the learning materials contained in the application. This test will be tested by Muhammadiyah Elementary School teachers with an assessment in the form of a questionnaire.

c. Learning Media Test

Testing is done with the aim of checking the programming aspect, design aspect, audio aspect, image aspect and writing aspect. This testing will be tested by learning media experts with a value in the form of a questionnaire.

d. Test on Potential Users

This test was conducted on students of Muhammadiyah Bruno Elementary School, the results

of this test will be in the form of a score. And calculated using a Likert scale with the following formula:

$$\bar{x} = \frac{\sum x}{n} \quad (1)$$

Information:

$\bar{x}$: Average score

n : Number of respondents

$\sum x$: Total Score

The results of the percentage are calculated using the following formula:

$$result = \frac{total\ score\ obtained}{n\ score}\ 100\% \quad (2)$$

2.6 Distribution

The distribution stage is the last stage that can be called the evaluation stage for users. This is done with the aim of the development that has been carried out to get input and criticism from users, so that in the future it will get better game application results. Distribution was given to student users at Muhammadiyah Bruno Elementary School and involved teachers in assisting in the use of the game. Applications with apk file format are distributed through the Google Play Store.

3. RESULTS AND DISCUSSION

3.1 Application design results

The following explains the results of making an educational game to introduce waste sorting with an explanation of each feature provided by the educational game.

a. Splash Screen

In the development of educational game applications, splash screens are used to display a text message or image when the user first opens the waste sorting application. The following is a display of the splash screen page in Figure 7 Below:

Figure 7. *Splash Screen*

b. Main Menu Page

This page contains the main menu display which contains the material menu button, main menu, game instructions menu, playing menu,exit menu, and the name of the game title which is shown in Figure 8 Below:

Figure 8. Main Menu

c. Learning Page

This page contains material related to the introduction of various types of waste, which is implemented with a game model that displays the function of the application and its development, such as Figure 9, Figure 10, Figure 11. Below:

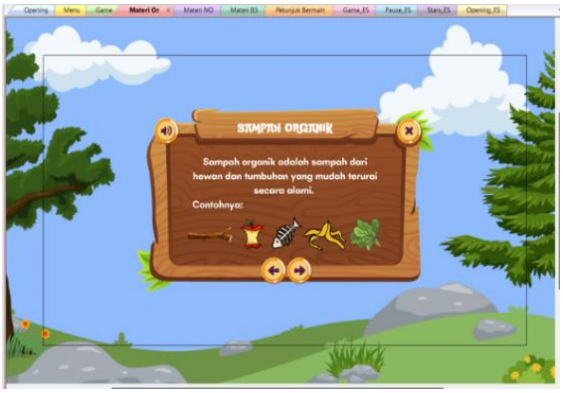

Figure 9. Organic Waste Material

Figure 10. Non-Organic Waste Material

Figure 11. B3 Waste Material

d. How to Play Page

This page contains a display of how or instructions for sorting waste in the waste recognition and sorting application, as in Figure 12 below:

Figure 12. How to Play Page

e. Play Page

This page contains a display of the waste sorting from this game, with a game model that displays a selection of waste that must be put into the trash according to its type, as shown in Figure 13 below:

Figure 13. Game Play Page

f. Score Page

The score page contains the results of the player's play, for each correct question, 10 points will be given. As seen in Figure 14 below:

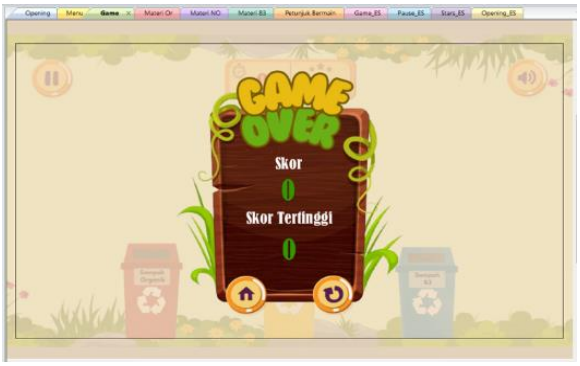

Figure 14. Score Page

3.2 Application Testing

1. Black Box Testing

Black box testing aims to ensure that the software functions in the game operate as expected, including verification that the data input and output processes run correctly. Device Test. The results of the test are shown in Table 3 below:

Table 3. Black Box Test Results

No	Menu	Process carried out	Result
1	*Splash Screen*	Show start button	Success
2	Main menu	Displaying question and sound buttons	Success
		Displaying Learn, Play and Exit buttons	
3	Learning Page	Displaying the material page for types of waste	Success
		Displays sound button to turn on or off	
		Displays an exit button to exit the learning page.	Success
		Displays the next page button to continue to the next material.	Success
		Displays the back page button to return to the previous material	Success
4	Play page	Showing the waste sorting game page	Success
		Displays sound buttons to turn music on or off.	Success
		Displays a pause button to pause the running game and restart it.	Success
5	Game over	Displays player scores	Success
		displays the home button to return to the main page.	Success
		Shows restart button to resume playing the game	Success
6	Exit	Displays a button to exit the application	Success

2. Learning Media Test

The test was conducted on one of the expert lecturers in the field of educational technology from the Islamic religious education study program. Based on the assessment results, this application received a score of 93.33% based on a Likert scale, which shows that this application is easy to use, interactive, and effective in helping to improve children's understanding. With these results, the application can be categorized as very feasible and recommended for use by target users. Success in technical aspects, navigation, and design appeal also strengthens the advantages of this application to support learning.

3. Learning Material Test

Based on the calculation results of the material test questionnaire given to teachers of Muhammadiyah Bruno Elementary School, this application received a score of 90%, which indicates that the material presented in the application is very much in accordance with the needs and expectations of users. Respondents assessed that this application has clear, interactive, and interesting material quality, and is able to support children's understanding effectively. With this score, the material in the application can be categorized as very suitable for use as a learning medium for children.

4. Test on potential users

This test was tested on students of Muhammadiyah Bruno Elementary School, where students played the game to get a score. This score is

used to assess the effectiveness and involvement of students in understanding the material presented through the game. The results of the test obtained an average score and percentage of 78.57%, it can be concluded that the majority of respondents gave a positive assessment, this value indicates that respondents tend to be satisfied, but there is still room for the maximum value.

4. CONCLUSION

Based on the results of research and testing, the educational game application for waste sorting, developed using the Multimedia Development Life Cycle (MDLC) method, demonstrated highly satisfying outcomes. The application achieved a score of 90% in the study material test, indicating that its content is highly relevant, straightforward, and interactive, effectively enhancing children's understanding of waste types and sorting. In the learning media test, the application received a score of 93.33%, showcasing a well-designed interface, smooth navigation, seamless transitions, and material compatibility tailored to children's needs. Furthermore, testing conducted with students at Muhammadiyah Bruno Elementary School produced an average score of 78.57%, reflecting good acceptance and positive feedback from the students. While most respondents expressed satisfaction, there is still room for improvement to maximize the application's performance and effectiveness. Overall, the application is categorized as "very suitable" for use as an interactive learning medium, supporting environmental education from an early age, particularly in waste management.

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