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# 3D RECYCLING GAME: RECYCLE CORNER

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Abstract

This project report presents the development and evaluation of "Recycle Corner," a 3D recycling game designed to educate children and teenagers about recycling practices. The game aims to enhance users' understanding of recycling through an interactive and engaging gameplay. The project addresses the critical need for innovative educational tools to foster environmental awareness and responsible behaviour among the younger generation. The game incorporates realistic scenarios where players sort different types of recyclable materials, providing immediate feedback to reinforce learning. Usability testing was conducted with 20 nine-year-old students from Sekolah Kebangsaan Merlimau 2, utilizing a structured questionnaire to assess effectiveness, efficiency, and satisfaction. The evaluation revealed a 71.9% usability score, indicating that the game effectively improves players' knowledge and attitudes towards recycling. However, the study identified limitations, such as the low poly design which makes it difficult for players to identify recyclable materials accurately, and the focus on only three types of recyclables, which are paper plastic and glasses, excluding other important categories like organic waste, metals, and electronic waste. Additionally, the game is currently only available on desktop computers, limiting its accessibility. Future recommendations include improving the visual detail and textures of recyclable items, expanding the scope to include additional recycling categories, and developing a mobile version of the game to increase accessibility and reach.

Keywords: Recycle;3D;Game;Recycling;Awareness

## INTRODUCTION

Recycling is the process of gathering, processing, and creating new goods out of items that would otherwise be regarded as garbage. By using this method, less garbage is transferred to landfills or incinerators, less energy is used, and fewer fresh raw materials are consumed. The materials that are recycled and repurposed take the place of raw materials that come from

natural resources including coal, natural gas, oil, mineral ores, and forests. This aids in the preservation of these scarce resources. Recycling also lessens the pollution that garbage disposal causes to the air, water, and land.

Since the 1st of September of 2015, the Malaysian government has made it mandatory to separate solid waste at the source. According to the Ministry of Housing and Local Government, this implementation is in pursuance of regulations under the Solid Waste and Public Cleansing Management Act 2007 (Act 672). Waste should be separated into two categories, which are residual waste and recyclable items. Residual waste refers to things that cannot be recycled such as organic waste, furniture, soiled materials, paper towels, etc. Meanwhile, recyclable items are categorized in terms of paper, plastic, and miscellaneous materials such as glass, aluminum, and electronics.

Recycling plays a crucial role in environmental conservation and resource sustainability. However, the practice of recycling has not been properly adapted by the people of Malaysia. While numerous campaigns of recycling such as Reuse, Reduce, Recycle (3R), Zero Waste Malaysia and Recycling Fantastic has been held for so many years as an initiative by the government and non-government organization of Malaysia, the recycling rate has increased significantly over the last few years, moving from just 15.7% back in 2015 to 28.1% as of the year 2019 (Teh, Z. Y, 2020). However, compared to another Asian countries, Malaysia's recycling rate is still one of the lowest amongst all (ITA, 2022). Some more strong endeavours are required in this era in order to increase our country's recycling rate for a better future of Malaysians.

Alongside with the rapid advancement of technology nowadays, game-based learning is being used universally, growing with immense potential for enhancing the learning experience of many. With people becoming tech-aware at an early age, educational games are becoming increasingly important in order to encourage them to fathom and put more interest in education. With the help of educational games, it can help not only kids and teenagers, but people of all ages to learn recycling practices alongside with enjoying the story and exciting mechanics of the educational game.

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## LITERATURE REVIEW

Recycling is a crucial component of sustainable environmental practices, serving as a systematic approach to manage and repurpose waste materials. The overarching goal of recycling is to minimize the strain on natural resources, reduce energy consumption, and mitigate environmental impact. As societies worldwide increasingly recognize the importance of sustainable practices, recycling plays a pivotal role in fostering a more eco-friendly and responsible approach to waste management.

### Common Type of Recyclables

Recyclables are a wide range of materials with the extraordinary capacity to be changed and utilized via recycling procedures. Recyclables, which range from everyday paper and plastics to glasses, represent both the material remains of our consumer-driven society and the possibility of sustainable resource management. They are an essential part of the circular economy model, which minimizes waste and lessens the demand on natural resources by reusing things continuously.

#### *Paper*

Paper is a versatile and widely used material that plays a crucial role in daily life, from packaging and printing to writing and hygiene products. It is primarily made from wood pulp derived from trees, although recycled paper utilizes post-consumer waste to reduce environmental impact. According to an article by the Environmental Protection Agency (EPA), paper recycling not only conserves trees but also saves significant amounts of energy and water compared to producing paper from virgin pulp. This process contributes to sustainability efforts by reducing greenhouse gas emissions and diverting waste from landfills.

#### *Plastic*

Plastics are synthetic materials derived from polymers, commonly made from petrochemicals, and are known for their versatility, durability, and cost-effectiveness. They are widely used in various forms, such as bottles, bags, and packaging. However, plastics pose significant environmental challenges due to their long decomposition times, leading to persistent pollution in landfills and natural environments. Recycling plastic is a crucial strategy to mitigate these issues, as it involves collecting and processing used plastics to create new

products, thereby reducing the need for virgin materials and minimizing environmental impact. Despite its benefits, recycling faces challenges like contamination and the complexity of sorting different types of plastics, which can hinder its effectiveness (Geyer et al., 2017).

***Glass***

Glass is a non-crystalline, often transparent material primarily composed of silica, with added components like soda and lime to modify its properties. It is used in various applications, such as window panes, tableware, and optics. Environmentally, glass is significant due to its non-biodegradable nature, but it has a lower environmental footprint compared to materials like plastic. One key advantage is that glass can be recycled indefinitely without losing quality, involving a process of collecting, cleaning, crushing into cullet, and melting to form new products. This recycling reduces raw material use, conserves energy, and decreases greenhouse gas emissions. However, challenges include contamination and the need for efficient collection systems (Edwards & Nabih, 2014).

**The Process of Recycling**

The recycling process begins with the collection of recyclable materials from homes, businesses, and recycling centres. These materials are then transported to a recycling facility, where they are sorted into different categories based on their type and composition. This sorting can be done manually or with the help of automated systems that use magnets, sensors, and other technologies to separate metals, plastics, paper, and glass. Proper sorting is crucial to ensure that the materials are clean and uncontaminated, which affects the efficiency and quality of the recycling process (Hopewell, Dvorak, & Kosior, 2009).

Once sorted, the materials undergo processing to prepare them for recycling. This typically involves cleaning to remove any impurities, labels, or residues. For instance, plastic bottles are washed to eliminate any remaining liquid or food particles. Metals are often shredded to make them easier to handle and melt. Glass is crushed into small pieces called cullet. This stage is essential to ensure that the recycled materials are free of contaminants that could interfere with the production of new products (Sthiannopkao & Wong, 2013).

After cleaning, the processed materials are then used to manufacture new products. Plastics are melted and formed into pellets that can be molded into new items like bottles or containers. Metals are melted down and cast into new shapes, such as cans or construction materials. Glass cullet is melted and reformed into new glass products, such as bottles or jars. Paper is pulped and reprocessed into new paper products. This step completes the recycling loop, turning old, used materials into new, usable products, thereby conserving resources and reducing the need for raw materials (Geyer et al., 2016).

**Recycling Practices in Malaysia**

With rapidly expanding cities and increasing populations, Malaysia as amongst the developing countries are facing numerous challenges in sustainably managing wastes and practicing ideal recycling practices. With limited space for landfills and rising costs of disposal, there is increased pressure and an urgent need to tackle the waste management issue and reduce the impact on the environment and general well-being of the population (MIDA, 2020).

***Infrastructure and facilities***

Malaysia has faced challenges in developing a comprehensive recycling infrastructure. There has been an effort to improve waste management facilities and recycling plants, but the progress has been gradual. The effectiveness of recycling programs depends on the availability and accessibility of recycling facilities. Waste recycling facilities are currently dispersed around the country, causing difficulties in recovering valuable waste materials and components that can be recycled. To mitigate this issue, the Waste Eco Park (WEP) incentive for developers, managers and operators was introduced under the Budget 2016 to centralize recycling companies from various industries under same locations. Through this initiative, a circular approach to waste management can be established in working towards zero waste production. (MIDA, 2020).

Other than that, there were also volunteers who are establishing their own recycling centers. The Malaysian branch of Buddhist Tzu Chi Charity Foundation which originated from Taiwan has made recycling one of its main charitable activities since its establishment in 1996. To date, Tzu Chi volunteers run and manage over 160 recycling centers and over 900 pick-up

points across Malaysia (Yusry. M, 2022). The success of Tzu Chi's efforts has led to Christian parishes being encouraged to hold their own recycling programs (Herald Malaysia, 2022).

### *2018 Malaysian Plastic Recycling Crisis*

In 2018, Malaysia faced a significant plastic crisis that garnered international attention. The country became a focal point in the global discussion on plastic waste management due to its role as a destination for imported plastic waste, particularly after China has launched the National Sword policy in January 2018, banning plastic waste imports which has then surged the imports of plastic waste into Malaysia. Malaysia has imported 195,444.46 metric tons of plastic waste from the United States (US) from January to July 2018 alone, in comparison to a total of 97,544 metric tons for January to November 2017 (Greenpeace, 2018).

There were regulation violations in the disposal of imported plastic waste to the country which plastic is burned on roadsides in the open-air, dumped in unregulated or poorly regulated dump sites close to bodies of water, discarded in abandoned buildings or just left to degrade and rot in the open thus contributing to water pollution, deforestation, and harm to local communities (Greenpeace, 2018). These wastes come primarily from developed countries, with the US, Japan, United Kingdom, being the top 3, and Australia, New Zealand, Finland, France, Belgium, Germany, Spain, Sweden and Switzerland as the rest. The 2018 Malaysian plastic crisis highlighted the urgent need for a comprehensive and sustainable approach to plastic waste management at both the national and international levels.

### Game-Based Learning

There appears to be a widespread belief that games are detrimental to the development of children (TeachThought, 2023). However, this is not the case. There are many benefits of game-based learning in helping children's cognitive development. It can increase a child's memory capacity as games often revolve around the utilization of memorization (TeachThought, 2023). This relates to games whereby children have to remember aspects to solve the game, memorize critical sequences, or track narrative elements. Other than that, it also helps in problem solving. Games like game-based learning help students solve problems by fostering skills like understanding causation, logic and decision making they can use in life outside of school (Nisbet. J, n.d).

## METHODOLOGY

Usability evaluation is used in this project's data collection to ensure that the interface and overall user experience are intuitive, efficient, and satisfying for the target audience. This method is essential because it directly involves users in the testing process, allowing valuable feedback on how they interact with the game. By observing and analyzing user behavior, pain points, usability issues, and areas for improvement can be identified, which might not be evident through other forms of data collection. Participants for this project are kids from 7 to 12 years old, with testing conducted at Sekolah Kebangsaan Merlimau 2. 20 students of 9-year-old were involved to ensure the game provides a positive and engaging experience for players. A list of usability testing questionnaires was created to evaluate the game effectively, gathering detailed feedback on various aspects of the game's interface, controls, mechanics, and overall player experience. After playing the game, testers received hardcopies of these questionnaires to fill out, ensuring their immediate reactions and insights were captured accurately.

## RESULT AND DISCUSSION

Based on the usability testing questionnaires provided, the results are analyzed by examining its Effectiveness, Efficiency and Satisfaction. These three components are essential in measuring the Usability of this project.

### Effectiveness

Effectiveness measures the capability of the user to complete a task from the game. As stated from article written by (M. Ismail et al, 2011), if a task is completed successfully, it will be marked as a ‘Yes’. A success mark is given the full credit of 100%. Tasks that are not completed successfully will be given a ‘No’ mark. ‘No’ marks are given zero (0%) credit. Unsuccessful tasks can include an event such as the child giving up, an event where the child is unable to complete a task on the first attempt or child completing tasks incorrectly, etc. Partial credit will also be made available in the form of a ‘Partial’ mark which will allow for 50% credit. Partial credit will be reserved for instances that will be up to the discretion of the

researcher to determine if the mistake should be given partial credit rather than a 'No' mark. Table 1 shows the summarization of the data:

Table 1: Summarized Effectiveness Data

| Answer | Subtotal |
|---|---|
| Yes | 124 |
| Partial | 12 |
| No | 64 |
| Total: | 200 |

Table 1 shows 10 tasks with 20 attempts per task, totaling 200 task attempts. 124 attempts were successful and 12 were partially successful. There are total of 64 unsuccessful tasks which will be ignored as 64 x 0% = 0. Therefore, to arrive at overall effectiveness rating for this set of tasks, equations are used as per following:

$$Effectiveness(\%) = \frac{Yes + (Partial \times 0.5)}{Total} \times 100\% \quad \textbf{1}$$

$$= \frac{124 + (12 \times 0.5)}{200} \times 100\% \quad \textbf{2}$$

$$= 65\% \quad \textbf{3}$$

**Efficiency**

Efficiency is measured for the smoothness in completing a task (M. Ismail et al, 2011). For measuring efficiency, the method and algorithm used is the same as measuring for effectiveness. Table 2 shows the summarization of the data:

Table 2: Summarized Efficiency Data

| Answer | Subtotal |
|---|---|
| Yes | 76 |
| Partial | 15 |
| No | 50 |
| Total: | 140 |

Table 2 shows 7 tasks with 20 attempts per task, totaling 140 task attempts. 76 attempts were successful and 15 were partially successful. There are a total of 50 unsuccessful tasks

which will be ignored as 50 x 0% = 0. Therefore, to arrive at overall efficiency rating for this set of tasks, equations are used as per following:

$$Efficiency(\%) = \frac{Yes + (Partial \times 0.5)}{Total} \times 100\% \quad \textbf{1}$$

$$= \frac{76 + (15 \times 0.5)}{140} \times 100\% \quad \textbf{2}$$

$$= 59.6\% \quad \textbf{3}$$

**Satisfaction**

Measures of satisfaction are taken using questionnaires with children. After playing the game, children will receive hard copies of these questionnaires to be filled out. The questions and answers are structured using a 5 point Likert scale. The scale ranged from 1 to 5 as shown in the Table 3 below:

Table 3: Likert scale

| Answer Option | Scale |
|---|---|
| Yes, very much | 5 |
| Yes | 4 |
| Moderate | 3 |
| Not really | 2 |
| Not at all | 1 |

Table 4: Satisfaction Evaluation

| Question | Rate | | | | | Subtotal |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | |
| How enjoyable was the game? | 0 | 1 | 0 | 1 | 18 | 96 |
| How easy was it to understand the game rules? | 0 | 0 | 2 | 4 | 14 | 92 |
| How intuitive were the game controls? | 0 | 1 | 2 | 5 | 12 | 94 |
| How would you rate the overall design of the game? | 0 | 2 | 4 | 2 | 12 | 84 |
| How helpful and clear was the instructions provided by the game? | 0 | 1 | 0 | 2 | 17 | 95 |
| How likely are you to recommend this game to a friend? | 0 | 1 | 2 | 5 | 12 | 88 |
| Did you find the game interesting? | 1 | 1 | 1 | 1 | 16 | 90 |
| Was the difficulty level of the game appropriate? | 0 | 1 | 2 | 2 | 15 | 91 |
| How satisfied are you with the game overall? | 0 | 1 | 2 | 2 | 15 | 91 |
| | | | | | TOTAL: | 821 |

Based on Table 4, each question answered by 20 children offers a potential positive response factor of 100 points using a 5-point Likert scale with a negative weighting of 1 and a positive weighting of 5, and for 9 questions, there are a total of 900 points or 100% satisfaction. We apply the following formula to determine the total game satisfaction rating:

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$$Satisfacction(\%) = \frac{Answer\ Point}{Total\ Point} \times 100\% \quad \textbf{1}$$

$$= \frac{821}{900} \times 100\% \quad \textbf{2}$$

$$= 91.2\% \quad \textbf{3}$$

**Results**

To measure the Usability percentage, we need to average those three components which are Effectiveness, Efficiency and Satisfaction. Therefore, the calculation are as follows:

$$Usability(\%) = \frac{65\% + 59.6\% + 91.2\%}{3} \times 100\% \quad \textbf{1}$$

$$= \frac{215.8\%}{3} \times 100\% \quad \textbf{2}$$

$$= 71.9\% \quad \textbf{3}$$

## CONCLUSION

In conclusion, this project successfully developed a 3D recycling puzzle game aimed at enhancing recycling education. The game was evaluated for usability, achieving a 71.9% usability score, indicating a positive user experience. Despite some limitations, such as the low poly design affecting material recognition and the focus on only three types of recyclables, the game proved effective in educating players. Recommendations for future work include improving visual details, expanding recyclable categories, and developing a mobile version to increase accessibility. Overall, the project demonstrates the potential of this game-based learning in promoting recycling awareness.

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