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**E-BOOK OF EXTENDED ABSTRACTS**

# AR GAME FOR LEARNING WASTE RECYCLING

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## ABSTRACT

Recycling education is crucial for promoting environmental awareness from a young age, which is why the Malaysian Ministry of Education introduced it in schools. However, current methods are not engaging enough to capture students' attention. A preliminary study at Sekolah Kebangsaan Merlimau 1 showed limited student participation due to unengaging programs and limited time. To address this, an Augmented Reality Game-Based Learning application was developed, allowing students to learn about recycling anytime and anywhere. Using the ADDIE methodology and marker-based via Vuforia in Unity, the game included incentives, personalised agents, and navigation tools to enhance motivation and knowledge retention. An evaluation with 30 students aged 7 to 12 using the Game Engagement Questionnaire resulted in an overall mean score of (2.14), indicating moderate engagement. Results show improved immersion and presence, with room to enhance absorption and flow. Future plans include multilingual support, progress tracking, and markerless Augmented Reality.

**Keywords:** *Augmented Reality, Game-Based Learning, Waste Recycling, ADDIE model, GEQ.*

## INTRODUCTION

Recycling is one of the most effective methods for preserving the environment and addressing the increasing problem of municipal solid waste, with Malaysia disposing of more than 39,000 tons daily (Zhou, 2022; ITA, 2024). Despite government efforts, the country's recycling rate still lags behind neighboring nations, emphasising the urgent need for strategic waste management and stronger public awareness. Research has shown that early environmental education plays a vital role in shaping children's knowledge, attitudes, and long-term behavior toward sustainability (Iwasaki, 2022). In line with this, the Malaysian Ministry of Education has incorporated recycling awareness into primary schools, including Sekolah Kebangsaan (SK) Merlimau 1 in Melaka. However, according to teacher Zuriyati Binti Bakar (personal communication, 10 July, 2025), student engagement in the school's recycling activities is often limited, with only 10 to 30 students actively participating, and programs are conducted just three to five times annually. Existing initiatives such as waste collection, awareness campaigns, competitions, and recycled art projects are entirely school-driven but face challenges in maintaining students' interest and consistency. Therefore, an alternative and more engaging platform is necessary to strengthen recycling education. Augmented Reality (AR) has been identified as a promising tool in education because it offers engaging learning experiences (Syafiq Yusof et al., 2022). When combined with Game-Based Learning (GBL), AR can further enhance motivation, focus, and retention through rewards, challenges, and hands-on interaction (Ying et al., 2021). This study proposes developing an AR-based game to teach recycling concepts such as waste collection, sorting, and pollution awareness through interactive levels and AR markers, creating both engagement and lasting knowledge retention.

## PROBLEM STATMENTS

### ***Current recycling educational initiatives demonstrate low levels of engagement***

According to Sihvonen et al., (2024) the challenge in educating children about environmental issues, such as recycling, lies in the limitations of traditional methods, which often struggle to engage young learners effectively. This is supported by a preliminary analysis, which highlights that students' sources of information about recycling primarily rely on text-based materials. According to the data, 11 students cited teachers as their main source, followed by social media (10 students), posters (5 students), and books (4

students). These sources are generally unappealing to students and often result in a lack of sustained interest, as learners tend to lose attention quickly when exposed to static and passive content.

### ***Limited exposure to do recycling education at school***

According to Teacher Zuriyati (personal communication, 10 July, 2025), recycling programs at school are conducted only three to five times per year, with each session lasting approximately two hours. As a result, students receive very limited exposure to recycling education. This is also supported by a preliminary analysis conducted on students at SK Merlimau 1, which shows that the main obstacles they face in practicing recycling are insufficient time and a lack of information. Based on the data, 21 students cited insufficient time, while 8 students identified a lack of information as the key challenge. Iwasaki (2022) emphasizes that environmental education at an early age is critical in shaping children's awareness and attitudes toward environmental responsibility. Students who receive limited exposure at a young age are more likely to have lower knowledge and a weaker understanding of important concepts like recycling.

## **OBJECTIVES**

- i. To design an engaging interface for an AR game-based learning application for primary students about waste recycling.
- ii. To develop an AR game-based learning application for primary students that teaches about waste recycling.
- iii. To evaluate students' engagement with the AR game-based learning application designed for waste recycling education.

## **METHODOLOGY**

This study adopts the ADDIE model which consists of several phases (analyze, design, development, implementation, and evaluation), as the guiding methodology for developing the AR game-based learning application. The ADDIE model is a widely recognised instructional design framework used across various disciplines to systematically create effective and learner-centered educational solutions (Anggala et al., 2022). Each phase of the model is applied in sequence to ensure the structured development and implementation of the AR educational game.

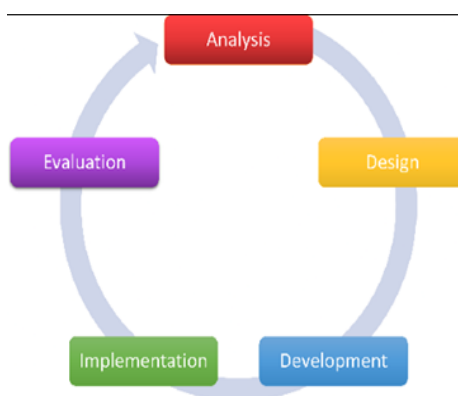


Figure 1: ADDIE Model phases.

In the analysis phase, a preliminary study was conducted to identify gaps in recycling education among primary school students. An online interview was carried out with teachers from SK Merlimau 1, and an online survey was distributed to 30 students to gather insights on current recycling practices and student engagement. The findings of this preliminary work highlighted limited exposure and a lack of interactive elements in existing programs. Additionally, a literature review was conducted to support the study's direction, guiding the selection of relevant content, target users, AR techniques, game genre, and GBL features. The literature revealed that a puzzle genre integrated with marker-based AR and GBL elements would be most effective in promoting engagement and environmental awareness.

During the design phase, the learning objectives and game structure were carefully planned to ensure an engaging educational experience. A flowchart was created to illustrate the gameplay sequence, user interactions, and system responses, serving as a visual guide to streamline development and identify logical inconsistencies. A low-fidelity storyboard was also developed to visualise the game's narrative, layout, and interactive components. This provided a clear framework for how educational content would be embedded within the game environment, ensuring alignment between learning goals and gameplay elements.

The development phase focused on producing all necessary materials and assets for the AR game based on the design specifications. Hardware and software requirements were identified, with development carried out on a laptop meeting the minimum technical specifications. The game was built using Unity as the primary engine, with the Vuforia SDK enabling marker-based AR functionality. Blender was used to create 3D models, while Adobe Illustrator 2025 was used for graphic assets. Once tools and resources were in place, a working prototype of the AR game was developed, integrating interactive recycling lessons and GBL features such as rewards, avatars, and navigation tools.

In the implementation phase, the AR game was deployed in APK format and tested with real users. Feedback from the users was crucial for improving the prototype before developing the final version, ensuring the application would be ready for end users.

The evaluation phase measured student engagement with the AR game using the Game Engagement Questionnaire (GEQ), which assesses four key elements: Immersion, Presence, Flow, and Absorption. A total of 30 students from SK Merlimau 1 participated in the evaluation. After playing the game, the students completed the questionnaire in hard-copy questionnaire. The questionnaire employed a 3-point Likert scale, and the collected responses were analysed to evaluate the effectiveness of the AR game in enhancing engagement as well as to identify potential areas for improvement.

RESULTS AND DISCUSSION

The evaluation results of the AR game-based learning application revealed varying levels of student engagement across four dimensions which is immersion, presence, flow, and absorption. Immersion achieved the highest mean score (2.53), indicating that students were highly mentally involved and engaged in the game environment, likely due to the use of AR features, interactive visuals, and real-time feedback. Presence also showed strong engagement (2.38), suggesting students felt a realistic sense of being in the virtual environment. In contrast, flow recorded a moderate mean score (1.97), showing that students experienced focused engagement at times but were unable to maintain it consistently. This was mainly due to language barriers, which made some instructions difficult to follow, and the technical requirement of scanning markers at specific distances, which occasionally disrupted gameplay. Similarly, absorption scored moderately (1.69), reflecting that while students were attentive, they struggled to achieve deep concentration. This was influenced by scanning difficulties related to distance and lighting conditions, which interrupted their overall focus.

Overall, the average engagement score across all 19 questionnaire items was (2.14), reflecting a moderate level of engagement. These findings demonstrate that the AR game was effective in capturing students' attention, especially through immersion and presence, but also highlight the need for improvement in maintaining flow and deep absorption through more dynamic and challenging gameplay.

Table 1: Mean Engagement Scores For Each Element

| Elements   | Mean Score | Engagement Level |
|------------|------------|------------------|
| Absorption | 1.69       | Moderate         |
| Presence   | 2.38       | High             |
| Flow       | 1.97       | Moderate         |
| Immersion  | 2.53       | High             |
| Overall    | 2.14       | Moderate         |

## CONCLUSION

The AR educational game developed in this study successfully enhances recycling awareness among primary school students by providing an engaging learning experience. Using marker-based AR combined with game-based learning features, the application increases students' interest and understanding of recycling concepts while promoting active involvement in the learning process. For teachers, it offers an alternative classroom tool that creates a dynamic, student-centered environment, while for parents it serves as an additional tool to support recycling education at home. All project objectives were achieved, including user interface design, AR game development, and evaluation of student engagement. The evaluation, conducted with the GEQ, revealed a moderate overall engagement level, with higher engagement in presence and immersion. However, moderate scores in flow and absorption indicate that sustained focus and deep involvement were hindered by language barriers and the requirement to scan markers at specific distances. Addressing these issues by introducing a Malay language option and adopting markerless AR technology could improve accessibility, reduce distractions, and create a smoother, more engaging learning experience for students in the future.

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