Raising Awareness of 3R (Reduce, Reuse, Recycle) Using Revin the Environment Hero Serious Game for Elementary Schoolers

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Abstract

Indonesia faces a significant environmental challenge with rising annual waste production, reaching 69.7 million tonnes in 2023, yet only 62.91% was properly managed. This problem stems from a lack of awareness about proper waste management, especially among children. To address this issue, this study developed Revin the Environment Hero, a serious game designed to enhance elementary school students' understanding of the 3R concept (Reduce, Reuse, Recycle). Employing a Research & Development approach with the ADDIE model, the game was tested with 40 elementary students in Surabaya. Pre-test and post-test questionnaires assessed the game's effectiveness, and a Paired Sample T-Test showed a significant improvement in students' 3R knowledge (t-value = -12.637, $p < 0.001$). Feedback revealed high satisfaction with the game's engaging narrative, interactive mechanics, and clear instructions. The game not only increased students' theoretical knowledge but also encouraged practical application of the 3R principles through creative recycling activities. These findings demonstrate the potential of serious games as effective educational tools for promoting environmental awareness and sustainable behaviors in young learners. Future studies should expand respondent diversity and include additional features, such as varied challenges and adjustable difficulty levels, to further enhance educational outcomes.

Keywords: Environmental Awareness, 3R Education (Reduce, Reuse, Recycle), Serious Game, Educational Game, Game Development

I. INTRODUCTION

One of Indonesia's biggest problems is the ever-increasing number of environmental wastes produced each year [1]. The biggest contributor to that problem is the deep-rooted bad habit of littering, which affects the majority of Indonesian residents [2]. Newest Indonesian environmental waste data published directly by Republic of Indonesia's Ministry of Environment and Forestry shows that based on data processing from 321 regencies and cities in Indonesia, their produced waste weighs 64 million tonnes per year in 2021 [3]. As of 2023, Indonesia has generated approximately 69.7 million tonnes of waste per year [4]. The amount of waste produced is expected to continue increasing every year. Out of all those, only 62.91% was successfully handled by waste processing authorities [5]. The exorbitant amount of environmental waste is mainly contributed by the lack of awareness of proper waste management methods, their environmental impacts, and habits by lots of Indonesian residents [6], [7]. This lack of awareness can be observed

daily, from illegal waste incineration, improper waste categorization, and littering on roads and water outlets like rivers, lakes, and seas. These habits, in turn, spur future problems including floods and pollution. Such habits are often shown by less educated residents of developing countries.

A possible remedy to this situation is to increase the awareness of proper waste management methods to Indonesian residents since their early years, to prevent the potential development of bad waste management habits. Effective methods to raise awareness about waste management should be implemented as early as possible during childhood [8], [9]. Numerous past researches show that there are many children who did not know how to properly manage waste and trash [9], [10]. The children had very little knowledge of what was important and what to do in managing waste and trash [11]. To increase children's awareness of waste management, specific media are needed to enhance engagement so that children can better understand waste processing and the importance of environmental preservation. Previous studies have utilized various media to teach children

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about the environment, including illustrated books [12], songs [13], animated videos [14], and games [15]. These media have been proven effective in increasing students' understanding and awareness of waste management and environmental care. Among these, games have been identified as one of the most effective media for improving comprehension and awareness [16], [17], [18], [19].

Serious games have proven to be an effective medium for teaching and raising awareness on various topics, offering a dynamic and interactive platform that fosters user engagement and enhances learning experiences. Studies highlight their ability to deliver complex content in an engaging and memorable manner, significantly improving knowledge retention and comprehension [20]. For instance, serious games have been successfully applied in healthcare education, such as raising awareness about pancreatic cancer, and in technical fields like cybersecurity and digital forensics [21], [22], where users benefit from the adaptability and self-paced learning these games provide [23]. Additionally, serious games have demonstrated effectiveness in teaching programming, making the process enjoyable while improving learners' problem-solving skills and understanding of computational thinking [24]. By leveraging interactive scenarios and immersive environments, serious games are uniquely positioned to combine education with entertainment, addressing various learning objectives across diverse disciplines.

Based on previous experiences and researches, an interactive media in the form of a serious game that educates students on proper waste and trash management is proposed as the solution. The serious game will educate about topics on 3R (Reduce, Reuse, Recycle) to students using interactive and fun games. The 3R topic is chosen because of its simplicity and ease of application, as the proposed education targets are young students to promote a stronger retention and earlier change in habits. The proposed implementation using serious game benefits in having more interesting ways to keep the young students hooked with the media, which administers knowledge on 3R techniques in little dosages to promote change in waste management behaviors. Unlike previous serious games that focused on cybersecurity [25] or traffic education [26], Revin the Environment Hero introduces a novel integration of crafting-based activities in environmental education for elementary students, which has been rarely explored in prior studies.

II. RESEARCH METHODOLOGY

This study employs a Research and Development (R&D) methodology using the ADDIE model, consisting of five stages: Analysis, Design, Development, Implementation, and Evaluation [27], [28], [29]. Figure 1 show the pipeline of ADDIE model. The ADDIE model provides a structured framework for instructional design and is widely applied in various educational contexts. In the analysis stage, a comprehensive needs assessment was conducted to identify gaps in elementary school students' awareness of the 3R

(Reduce, Reuse, Recycle) concept [30]. This involved reviewing existing environmental education materials and conducting preliminary observations and discussions with teachers. The design stage focused on structuring educational content and designing the serious game "Revin the Environment Hero" to effectively convey the 3R principles [31]. This phase involved conceptualizing game mechanics, developing storylines, and designing user interfaces suitable for elementary school students.

In the development stage, the game was created using the Unity Engine, incorporating interactive and engaging gameplay elements tailored to young learners [32]. The game development process involved iterative testing to ensure smooth functionality, age-appropriate difficulty levels, and engaging visual and auditory elements that enhance user experience. The implementation stage included a trial session where 40 elementary school students in Surabaya, Indonesia, participated in playing the game. The trial aimed to assess the game's usability, engagement level, and effectiveness in teaching the 3R principles. Students were guided through the gameplay experience, and facilitators were available to provide necessary instructions and support. This session provided valuable insights into students' interactions with the game, helping to refine its content and mechanics before formal evaluation.

Figure 1. Pipeline ADDIE

The evaluation stage assessed the game's effectiveness using a pre-test and post-test questionnaire administered to the 40 participating students. The primary data collected aimed to measure changes in students' understanding of the 3R principles before and after engaging with the game. The research employed a quantitative approach, with data analyzed using statistical techniques. A Paired Sample T-Test was conducted using IBM SPSS Statistics 29 to compare pre-test and post-test scores, providing insights into the game's impact on students' environmental awareness. Additionally, qualitative feedback on the game's usability and engagement was gathered through a Google Form questionnaire. This feedback was analyzed descriptively to identify areas for improvement and gauge overall user satisfaction. The combination of quantitative and qualitative data ensured a comprehensive evaluation of the game's effectiveness as an educational tool for promoting sustainability among elementary students.

III. RESULTS AND DISCUSSION

The results of this study highlight the development and evaluation of Revin the Environment Hero, a serious game designed to enhance elementary school students' awareness of the 3R (Reduce, Reuse, Recycle) concept. This game integrates interactive learning elements with engaging gameplay to effectively convey environmental sustainability

principles. Through structured assessments, including pre-test and post-test evaluations, the study measures the game's impact on students' understanding and application of 3R concepts. Additionally, user feedback was collected to assess engagement and usability, providing insights into the game's effectiveness as an educational tool. The following sections present a detailed analysis of the game's outcomes and its potential for further improvement.

A. Analysis Stage

The analysis was conducted by distributing questionnaires to children to evaluate their knowledge and understanding of the 3R (Reduce, Reuse, Recycle) concept. The questionnaire targeted children aged 7-12 years, a critical age for developing environmental awareness. Since young children may face difficulties in comprehending complex questions, their parents assisted them while filling out the questionnaire to ensure clarity and accuracy of responses. The survey aimed to assess not only their theoretical knowledge but also their ability to apply 3R principles in daily life.

The findings revealed that while most children had a basic awareness of 3R, their ability to implement these principles was still lacking. Many children showed a good understanding of Reuse, as they often repurposed items such as bottles, papers, and plastic containers. However, their comprehension of Recycling and Reducing was weaker. Some respondents struggled to identify which materials could be recycled, and others did not fully understand the impact of excessive waste production. The concept of Reduce, which involves minimizing waste from the source, was the least understood. These results highlight the need for further education and practical demonstrations to help children develop better habits and a stronger commitment to sustainable waste management practices.

B. Design Stage

The game design process focused on developing engaging mechanics, an educational narrative, and an intuitive user interface to promote 3R (Reduce, Reuse, Recycle) awareness among children. Recyclable items were carefully selected to demonstrate real-world applications, allowing players to transform discarded materials into useful objects such as tote bags, flower vases, and bookshelves. These elements not only reinforce sustainability concepts but also encourage creativity in repurposing waste. The storyline follows Revin, an elementary school student who becomes environmentally conscious after an inspiring lesson from his teacher. As he explores locations like a polluted river, a littered schoolyard, and a recycling workshop, players help him complete tasks that emphasize problem-solving and critical thinking related to 3R practices.

Using the MDA (Mechanics, Dynamics, Aesthetics) framework, the game ensures smooth and interactive gameplay. Players can control Revin to walk, interact with objects, and communicate with NPCs, fostering an immersive experience. The mechanics are designed to be intuitive, ensuring that children can easily navigate and engage with the game's objectives. The user interface is developed to be visually appealing and child-friendly, with clear icons and interactive elements that enhance accessibility. Through a combination of compelling storytelling, interactive learning, and engaging visuals, the game effectively teaches children about sustainable waste management in an enjoyable way.

C. Development Stage

The game was developed using the C# programming language and the Unity game engine, ensuring a smooth and interactive experience. The development process began with importing assets into Unity, including characters, backgrounds, and interactive objects. At this stage, various user interfaces were designed, such as the main menu, cutscenes, school environment, and the open-world interface, ensuring a cohesive and engaging gameplay experience. Each stage of the game was implemented sequentially, incorporating different scenarios that teach players about 3R (Reduce, Reuse, Recycle) practices. As shown in Figure 2, the game begins when the player presses the start button, introducing the story of Revin, the main character. Before diving into gameplay, players receive a set of instructions to help them understand the controls and objectives.

Figure 2. Screenshot of The Game

Once inside the game, players must complete various tasks that promote environmental awareness, such as collecting trash and sorting waste into appropriate bins. Movement mechanics were programmed to allow players to navigate the environment seamlessly, ensuring an intuitive experience. To enhance engagement, interactive elements such as dialogues with NPCs and visual cues were integrated, guiding players in understanding the importance of waste management. As the game progresses, players face increasingly complex challenges that test their knowledge of the 3R concept, reinforcing learning through interactive gameplay.

Beyond waste collection, the game emphasizes the creative aspect of recycling by allowing players to transform used materials into functional items. As illustrated in Figure 3, players can craft various products, such as plant pots, flower vases, and tablecloths, using discarded items. Some missions involve step-by-step crafting activities where players cut, assemble, and design objects, simulating real-life recycling practices. This hands-on approach not only strengthens the educational aspect of the game but also encourages players to think critically about repurposing materials in their daily lives.

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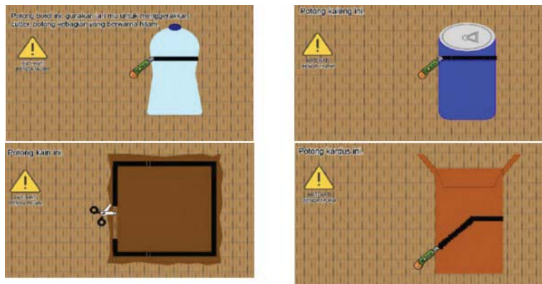
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Figure 3. Create Various Craft Products

By integrating engaging mechanics, an interactive storyline, and an immersive environment, the game successfully raises awareness of environmental sustainability. Through completing missions, crafting items, and interacting with the game world, players gradually develop a deeper understanding of 3R principles. The development process ensured that every aspect of the game was designed to be both educational and enjoyable, making it an effective tool for instilling environmental consciousness in young players.

D. Implementation Stage

The implementation stage of Revin the Environment Hero involved testing the game with 40 elementary school students from Surabaya to evaluate its effectiveness in increasing awareness and understanding of the 3R (Reduce, Reuse, Recycle) concept. The testing process was designed to measure both cognitive improvement and user engagement. Before playing the game, all participants took a pre-test to assess their initial knowledge of 3R principles. The pre-test consisted of multiple-choice and short-answer questions aimed at identifying gaps in their understanding. Additionally, the students were asked about their confidence in handling recyclable materials and their familiarity with proper waste management practices.

Following the pre-test, the students played the game for approximately 20 to 30 minutes. During this time, they interacted with the main character, Revin, completed missions related to waste sorting, and participated in crafting activities that transformed used materials into functional products. The game's engaging mechanics and interactive storytelling allowed students to actively apply 3R concepts in a simulated environment. Throughout the gameplay session, facilitators observed the students' engagement levels, noting their reactions to different challenges and their ability to follow the game's instructions. The students displayed curiosity and enthusiasm, especially during the crafting stages, which reinforced the importance of recycling and reusing materials.

After completing the game, the students took a post-test to measure any improvements in their understanding of the 3R concept. This test contained similar questions to the pre-test, ensuring a direct comparison of results. The post-test also included additional questions regarding their opinions on the game, such as whether they found it enjoyable, easy to understand, and helpful in learning about environmental sustainability. The results showed a noticeable improvement in their knowledge, as reflected in the increased number of correct answers compared to the pre-test. Before playing the game, many students struggled with distinguishing between Recycle and Reduce, often confusing their definitions and applications. However, after gameplay, most students were able to correctly identify and explain each component of the 3R concept.

Table 1 provides a detailed comparison of the number of correct answers given by students during the pre-test and post-test phases, clearly illustrating the effectiveness of the game as a tool to support educational outcomes. The questions used in both tests were adapted from validated environmental education journals [33], [34] and were further reviewed by an elementary school teacher to ensure clarity, age appropriateness, and relevance to the 3R (Reduce, Reuse, Recycle) learning objectives. In addition, the students expressed positive feedback, noting that they considered the game not only enjoyable to play but also informative, which highlights its promising potential for wider implementation in the context of environmental education.

Table 1. Results of the Pre-Test & Post-Test Question on 3R

Questions	Correct	
	Pre-Test	Post-Test
What is meant by the 3R concept?	97.5%	100%
Which one is considered part of "Reuse" concept?	62.5%	100%
Which one is considered part of "Reduce" concept?	47.5%	100%
Which one is considered part of "Recycle" concept?	12.25%	100%
Why should we reuse items that can be used again?	70%	100%
Why should we apply Reduce?	62.5%	100%
Why should waste be sorted first?	7.5%	100%
Give an example of a Reuse practice that you can do.	60%	100%
Give an example of a Reduce practice that you can do.	5%	100%
Give an example of a Recycle practice that you can do.	57.5%	97.5%

E. Evaluation Stage

In the evaluation stage, an analysis was conducted using the Paired Sample T-Test with IBM SPSS Statistics 29 to measure the effectiveness of Revin the Environment Hero in improving students' understanding of the 3R concept. This evaluation compared pre-test and post-test results to determine whether playing the game led to a significant increase in knowledge. Additionally, qualitative feedback was collected from respondents, including their critiques and suggestions for improving the game. This feedback helped assess the overall user experience, engagement level, and potential areas for future development.

The statistical analysis using the Paired Sample T-Test revealed a significant improvement in scores. The test results showed a t-value of -12.637 with degrees of freedom (df) = 39,

indicating a strong change in students' understanding of 3R concepts. Furthermore, the p-value (Two-Tailed) was < 0.001, confirming that the difference between pre-test and post-test scores was statistically significant. This result, presented in Table 2, demonstrates that students exhibited a meaningful increase in their knowledge after playing the game.

The feedback provided by respondents further supported the effectiveness of the game. Many students reported that the game was enjoyable, easy to understand, and helped them visualize how to apply the 3R principles in real life. Several participants mentioned that the visual and auditory elements contributed to their learning experience, making the concepts more memorable. Moreover, the storyline and character design were considered appealing, which maintained students' interest throughout the gameplay. However, some suggested additional levels and interactive elements to make learning even more engaging. Overall, the evaluation confirmed that Revin the Environment Hero successfully enhanced students' awareness of environmental sustainability through an interactive and engaging approach.

Tabel 2. The result of Paired Sample T-Test Statistical Test for Question on 3R

	t	df	Sig. (Two-Tailed)
Pair; Pre-Test & Post-Test	-12.637	39	< 0.001

The questionnaire distributed to respondents contained four questions measured using a 5-point Likert scale to assess their feedback on the game. The responses were collected from students who had completed the game, providing insights into their level of satisfaction and overall experience. The results indicated that most participants rated their satisfaction between "quite satisfied" and "satisfied" with the final version of Revin the Environment Hero.

Students found the game engaging, with various interesting challenges that kept them motivated throughout gameplay. They also appreciated the clarity of the game's purpose and the guidance provided at each stage. The instructions were designed to be simple and easy to understand, making them accessible even for elementary school students. Additionally, the interactive nature of the game helped reinforce their understanding of the 3R (Reduce, Reuse, Recycle) concept in an enjoyable way.

Overall, the feedback suggested that the game was effective in educating students about environmental conservation while maintaining a high level of engagement. Some students expressed interest in additional challenges or extended gameplay to further enhance their learning experience. Table 3 presents a detailed breakdown of the game feedback results, highlighting the positive reception and areas for potential improvement.

Tabel 3. Game Feedback Results

Questions	Score
Does the game provide enough variety of challenges?	3.4
Does the game have a clear objective?	3.85
Are the instructions in the game clear enough and helpful in understanding how to play the game?	3.7
Does the game help you understand the 3R concept better?	3.7

Players provided several suggestions for improving Revin the Environment Hero to enhance engagement and educational value. One recommendation was to introduce new obstacles at each level to increase gameplay variety and maintain player interest. Additionally, respondents suggested incorporating adjustable difficulty levels, allowing players to select a challenge level that suits their abilities, ensuring the game remains engaging without being too easy or too difficult. Another key suggestion was to expand the range of recycled items that players can create, offering more crafting options to reinforce the concept of reusing materials in diverse ways. By implementing these improvements, the game could provide a more immersive and dynamic learning experience while further strengthening players' understanding of 3R (Reduce, Reuse, Recycle) principles. These enhancements would help maintain motivation, encourage problem-solving, and create a more personalized educational journey for different types of learners.

F. Discussion

The significant improvement in 3R knowledge observed between the pre-test and post-test results demonstrates the effectiveness of Revin the Environment Hero. The large effect size (t-value = -12.637, $p < 0.001$) indicates a notable enhancement in students' understanding and application of the 3R concepts, highlighting the game's ability to support meaningful learning [16], [17]. This finding aligns with extensive research showing that serious games are highly effective in improving environmental education outcomes by making abstract concepts more accessible and engaging for young learners [35].

The game's success can be attributed to its thoughtful design, which includes an engaging narrative, interactive mechanics, and clear, age-appropriate instructions. These features cater to the cognitive needs of elementary school children, aligning with best practices in educational game design [18]. By immersing students in an enjoyable learning experience, the game supports better knowledge retention and practical application [19]. This result mirrors findings from previous studies emphasizing that interactive and engaging learning environments can significantly enhance students' understanding and long-term retention of educational content [15].

The improvements in students' understanding of the 3R concepts are consistent with research on the effectiveness of serious games in environmental education [15]. Studies frequently report that serious games not only improve

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knowledge but also encourage behavioral changes by providing interactive and hands-on learning experiences [36]. Similarly, Revin the Environment Hero successfully motivates students to actively engage with the 3R principles through a combination of interactive gameplay and relatable, real-world scenarios, demonstrating the potential of serious games to deliver impactful educational outcomes.

The Revin the Environment Hero game shows promising potential in bridging the gap between students' theoretical and practical understanding of 3R concepts. Through creative recycling activities and hands-on learning, the game fosters behavioral change and engages students in meaningful, enjoyable ways. Positive feedback highlights its educational value and reinforces the potential of serious games as impactful tools for promoting environmental awareness and sustainable habits in young learners.

IV. CONCLUSION

This study demonstrates that the Revin the Environment Hero game significantly enhances elementary students' understanding and application of the 3R (Reduce, Reuse, Recycle) concept, as evidenced by the statistically significant improvement in post-test scores compared to pre-test results (t-value = -12.637, p < 0.001). The game's engaging narrative, interactive mechanics, and age-appropriate instructions effectively capture students' attention and encourage active participation, making learning both enjoyable and impactful. Additionally, the incorporation of creative recycling activities allows students to practice 3R principles in a meaningful way, reinforcing their conceptual understanding while fostering environmentally responsible behaviors. By combining education with gamification, the game not only increases knowledge retention but also promotes positive behavioral change. Future research should focus on enhancing the game with additional challenges, varied tasks, and adjustable difficulty levels to cater to different learning paces. Furthermore, expanding the study to include a larger and more diverse sample would strengthen the validity of the findings and ensure the game's applicability across different educational settings. These improvements could further optimize the game's effectiveness as an engaging tool for teaching sustainability concepts to young learners.

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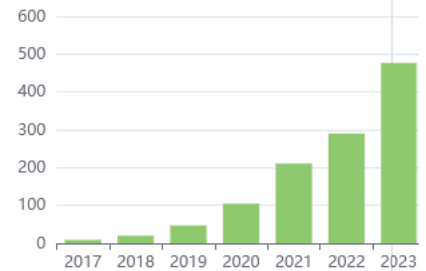📍 INSTITUT INFORMATIKA INDONESIA SURABAYA

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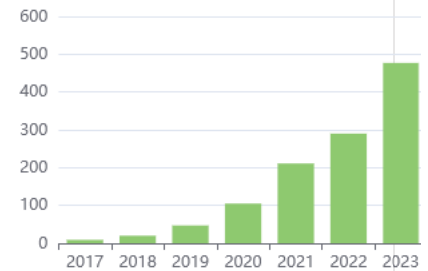**Implementation of Machine Learning Model to Detect Sign Language Movement in SIBI Learning Media**

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