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Let's Upcycle: Upcycling Awareness Mobile Application Using Game-based Learning Approach

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Abstract: Upcycling involves reusing materials to create new products, enhancing their value and helping to reduce waste. However, a lack of knowledge and awareness about upcycling can hinder its adoption, presenting a significant challenge. To address this issue, the "Let's Upcycle" mobile game application was developed to raise awareness and offer practical upcycling ideas to the general public. The application employs a game-based learning approach combined with gamification and was created using the ADDIE methodology to streamline the development process. The project's effectiveness was assessed through a User Experience Questionnaire, which yielded positive feedback of 91.1 percent regarding overall user experience. However, the app has some limitations, such as being available only in English and compatible solely with Android devices. Future updates will aim to address these issues.

Keywords: *Upcycling, Game-based Learning, Mobile Application, ADDIE methodology, user experience*

1. Introduction

Upcycling is popularly understood as an umbrella concept incorporating 'creative' forms of repair, reuse, repurpose, refurbishment, upgrade, remanufacture, and recycling (Sung et al., 2018). Utilizing objects that would typically be discarded in a better way is possible through upcycling, upcycling is operationally defined as a process in which a discarded material is re-utilized, and transformed into a product of higher value than its original status (Yoo et al., 2021).

Upcycling waste products is something that should be taken care of as it is one of the ways to protect the environment from being polluted by the amount of trash produced around the world. Upcycling is regarded as a strategy to reduce environmental impacts by combining circular material flows with slower production of materials and slower cycles of consumption (Singh et al., 2019). Although there is growing awareness of the urgency to address environmental challenges and an increased understanding of the mechanisms for achieving sustainability in recent years, upcycling still has a long way to go before it becomes a common practice among people.

Game-based learning (GBL) refers to redesigning the basic instructional task to make it more interesting, meaningful, and ultimately more effective for learning. (Plass & Pawar, 2020). The adaptation of digital instruction has been suggested to be a major emerging instructional advance that may shape the future of education (Zhang & Aslan, 2021). Previous research has shown that adaptation is a promising instructional technique in game-based learning (Wouters & van Oostendorp, 2017).

Therefore, to raise awareness and provide basic knowledge about upcycling, a game-based learning approach was proposed and developed. This game enables users to engage with and grasp the concept of upcycling while enjoying the gameplay. The fun and interactive experience not only captures users' attention but also motivates them to learn about and embrace upcycling.

2. Literature Review

Up-cycling is the conversion of waste materials to something useful or valuable, underlining is a useful concept that can be applied not only to the waste design industry but also to waste recycling and resource circulation (Yi et al., 2019). Upcycle uses the Do It Yourself (DIY) concept. DIY in upcycling is an approach to recycling that involves turning waste materials into useful objects. Initiatives for product sharing, mending, and repairing can avoid the purchase of new goods and replacement components and are consequently seen as ecologically friendly (Sung, 2017).

In recent years, smart technology has emerged in the educational domain as a tool to make learning more efficient. Research shows that the application of mobile learning as well as the use of game-based instructional strategies promotes students' learning and engagement (Chang & Hwang, 2019). Game-based learning (GBL) solutions can enable reflective, experiential, and intriguing learning environments (Bygstad et al., 2022). According to project management teachers, GBL methods may provide students with a memorable learning experience by affecting their emotions. (Jääskä & Aaltonen, 2022). Satrio et al. (2020) Recognized that the use of game-based learning will provide a better learning experience when it can collaborate with learning that provides instruction or guidance to students.

Specific to games, social influence has been found to positively influence the adoption and use of mobile games. (Baabdullah, 2018). Peer recommendations are significantly influential in virtual communities (Wang et al., 2020), including mobile gaming (Wang, 2022). Users can access the application anytime and carry it anywhere, as nearly everyone has a smartphone these days.

One of the popular models used in the field of instructional design as a guide for creating an effective design is the ADDIE model. The ADDIE model plays a crucial role in enhancing the competencies of secondary school teachers in designing effective instructional strategies (Handrianto et al., 2021).

3. Methodology

The following subsections demonstrate the flow of implementing the research idea using the ADDIE methodology phases: analysis, design, development, implementation and evaluation.

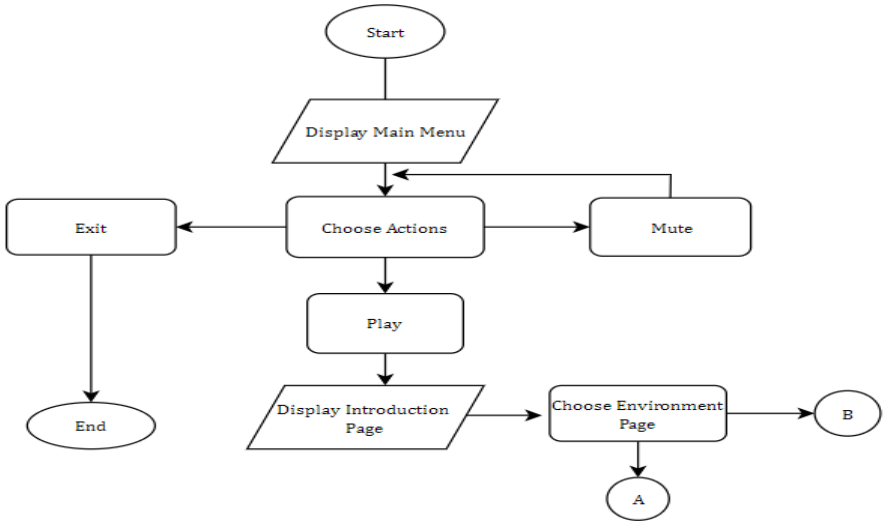
Analysis

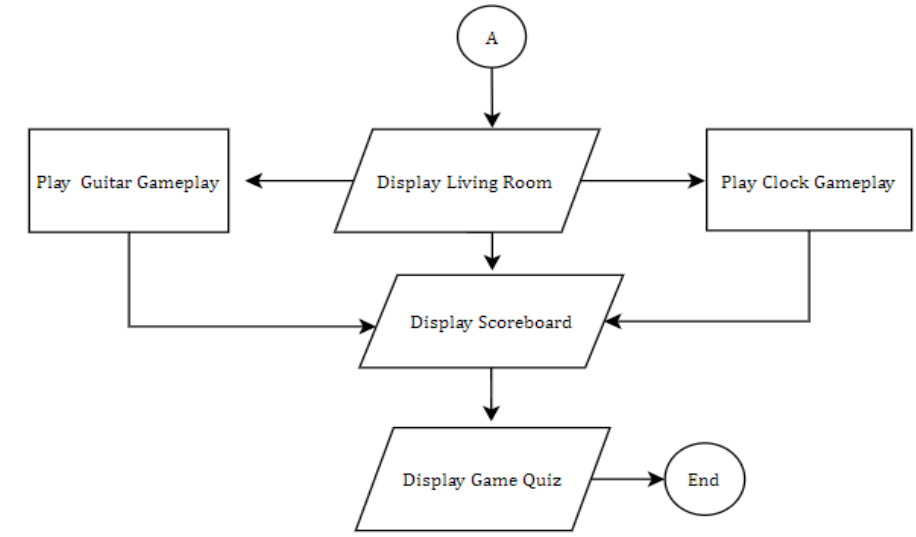
The project started by gathering information from various sources, including journals, trusted websites, and articles that provided in-depth insights into the topic. It identified a lack of knowledge and awareness about upcycling and a lack of creative ideas to upcycle things that are not being used anymore. The project objectives were to develop a mobile game application that educates users about upcycling through game-based learning and to evaluate the user experience using the User Experience Question (UEQ).

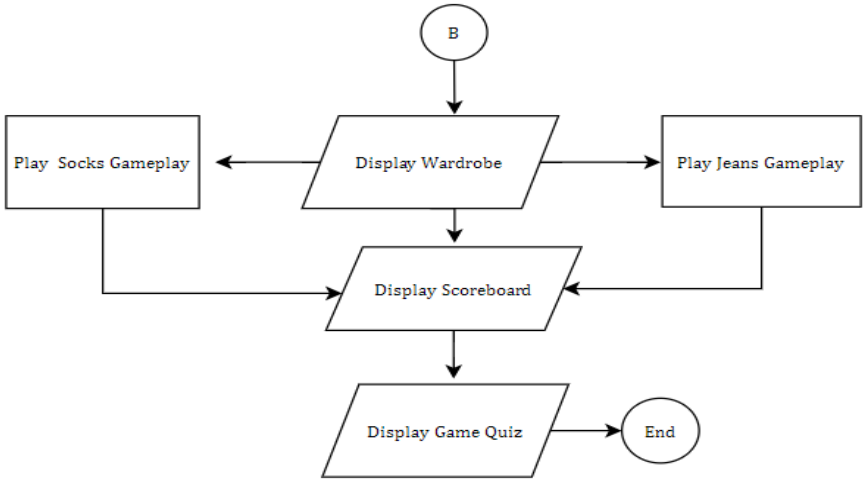
Design

The game's storyline was developed to make sure that the project's goals were met. A low-fidelity storyboard was created to visualize the game flow. The functions and the elements were identified and elaborated. The hardware and software that were needed for this game were downloaded and prepared for development. Design tools such as Canva, IbisPaintX, and Paint3D were utilized, while Audacity was used for audio editing, and Construct 3 served as the game engine. Figure 1 illustrates the overall flow of steps for the application.

Figure 1: Flowchart for Let's Upcycle Mobile-Based Application







Development

For the development phase, the required 2D elements for the game were created using IbisPaintX. The background images, buttons, sprites and animations were designed. The sprites were drawn layer by layer as the parts of the 2D elements had to be separated to produce moving-like animations and illustrations.

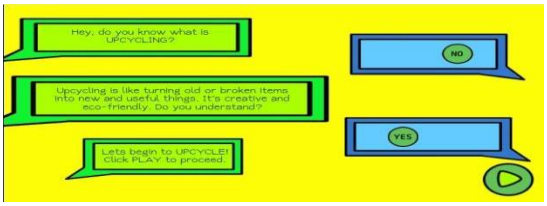
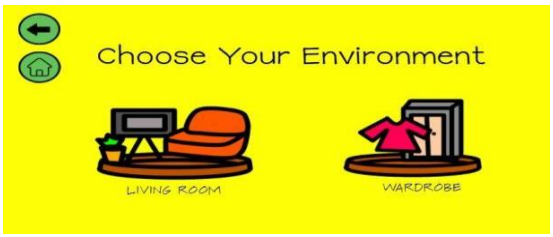
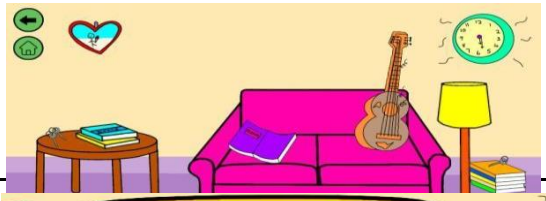
After designing the 2D elements, text elements were added to Construct 3 for the game title and instructions. Fonts were selected from websites offering free commercial fonts and imported into Construct 3. Importing the fonts into the project file was essential, as fonts could display differently on various devices if they were not available, making this step crucial to ensure consistency.

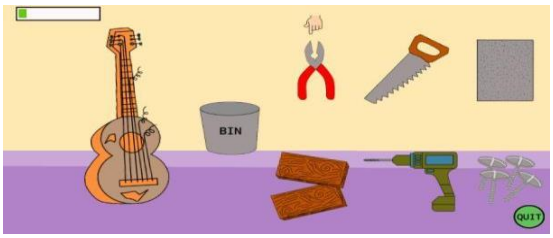
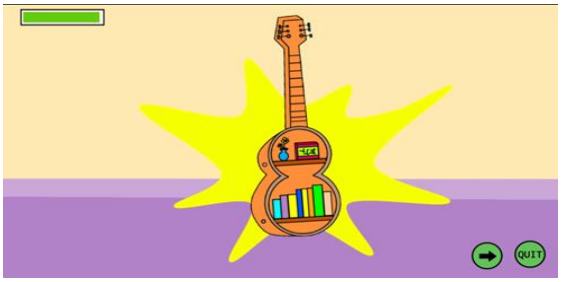
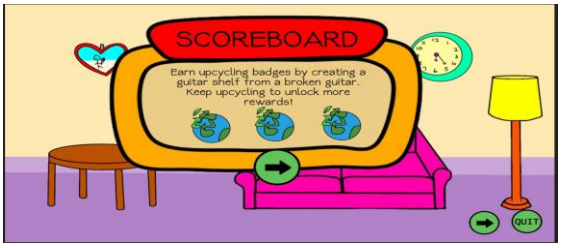
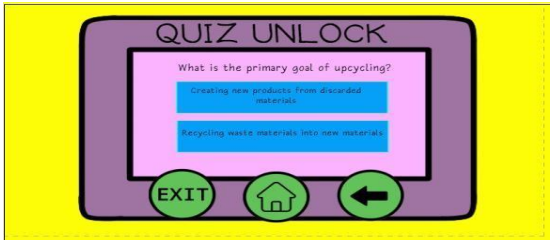
The objects created during the design phase were transferred to Construct 3 for game development. Animations and sprites were added to the layouts and arranged according to the storyline sequence. The interface included buttons, background images, and animations. Layouts and event sheets were incorporated into the project file, with event sheets scripted to implement animation movements and functions.

Background music and sound effects were edited using Audacity. Noise reduction techniques were applied to enhance audio quality. Sound effects were imported to match the animations, and background music was added

to improve immersion in the gameplay. Fig. 2 illustrates the high-fidelity storyboard for more visual detail.

Figure 2: High Fidelity Storyboard

	This is the Main Menu page. 3 buttons can be pressed. The button with the 'play' logo will direct the user to the introduction page. The mute button will mute the background music. The exit button will close the window.
	This is an introduction page, where the player is introduced to upcycling. This page contains conversation-like text and interactive buttons (YES/NO) to accept the answer from the user.
	This is the scene where the player needs to click and choose the environment where they are going to upcycle things.
	If the player chooses a living room environment, the instruction popup window will automatically appear. Users are asked to find the broken items in the living room.
	This is the living room environment. Players need to find the items that look broken in the living rooms and click on the item to upcycle.
	If the player clicks on the broken items (e.g. Guitar, Clock), the instruction popup window will automatically appear. Then, if the user clicks on the play button the user will be redirected to a gameplay page.

	This is the living room gameplay scene where the player is instructed to upcycle the item chosen step by step while following the hand instructions. Players need to drag and drop the objects/double-tap the objects according to the hand's instructions. The progress bar shows the progress of the upcycling process.
	This is the finished product scene when the user completes the step by step of the upcycling process. The final product is shown on the screen. This is an example of a broken guitar turning into a shelf.
 +	The Scoreboard popup shows the badges that were gained by completing the gameplay. Players get up to 3 badges if they complete the game and can unlock quiz rewards. The home button will be redirected to the home page.
	The quiz unlock page shows when a player gets 3 badges by completing the upcycling games. If the user clicks on quit the game, the badges will decrease and the player cannot access the quiz section. Players will get more badges if they complete the upcycling process. The EXIT button will close the window and exit the game. The HOME button will redirect to the homepage and the BACK button will redirect to the Choose Environment page. More items players upcycle, more quizzes unlock.

Implementation

Implementation follows the development stage in the ADDIE model. During this phase, the game prototype is finalized, to deliver content seamlessly and effectively. The game is exported as an APK file for usability testing. This testing assesses the game's quality, identifying any lags, errors, or bugs that need to be addressed. Issues are resolved based on user feedback, ensuring the game runs smoothly and is free of errors.

Evaluation

The evaluation phase involves public testing of the game. During this phase, a survey was conducted to assess user experience. The application was tested by 36 users to ensure that the goals of raising awareness among the public about upcycling were met. A Google Form containing download links for the application was distributed through various social media platforms, including WhatsApp, Instagram, and Telegram.

Participants were asked to complete all questions in the form and submit their responses.

The project's evaluation aimed to assess user experience, specifically focusing on the mobile game-based learning application. A Google Form survey was designed with two sections: one for gathering demographic data and the other for collecting feedback through a user evaluation questionnaire. A total of 36 respondents participated in the project testing phase.

The demographic findings based on the questionnaire results are presented in Table 1. The participants' ages ranged from 13 to 45 years old, with the youngest being 13 and the oldest being 45. Among the participants, 23 individuals (63.8%) were in their 20s, 12 participants (33.5%) were below 20 years old, and 1 participant (2.8%) was above 30 years old. The majority of people who took part in the survey were in their 20s. Out of all the participants, 35 (97.2%) were students. Furthermore, the survey had a higher representation of female participants, with a total of 33 individuals (91.7%) identifying as female.

Table 1: Demography of participants for Let's Upcycle

Question	Range	Frequency(n)	Percentage(%)
Age	19 and below	12	33.5
	20 - 29	23	63.8
	30 and above	1	2.9
Job	Full-time job	0	0.00
	Part-time job	0	0.00
	Student	35	97.2
	Unemployed	1	2.8
Gender	Female	33	91.7
	Male	3	8.3

To evaluate user experience, the questionnaire was adapted from the User Experience Questionnaire (UEQ). Participants answered a total of 20 questions, covering the dimensions of Attractiveness (A), Perspicuity (P), Dependability (D), Effectiveness (U), Novelty (N), and Simulation (S).

4. Results and Discussion

This section discusses the results and findings from the study. The mean values for evaluating the user experience of the game based on UEQ are presented in Table 2.

Table 2: Overall Mean Value

User Experience	Mean
Attractiveness	4.69
Perspicuity	4.53
Dependability	4.39
Effectiveness	4.51
Novelty	4.54
Simulation	4.66
Overall Mean	4.56
Overall Percentage (%)	91.1

The mean results of the game evaluation show that the attractiveness dimension scored highest at 4.69, closely followed by the perspicuity dimension at 4.53. The effectiveness dimension obtained a score of 4.51, while both the dependability and simulation dimensions scored 4.4. The novelty dimension received the same score of 4.4. Overall, the game achieved a positive user experience with an impressive overall mean of 4.56 and the overall percentage of user satisfaction is 91.1%., indicating a high level of satisfaction among users.

The results show the game received positive feedback across all evaluated dimensions, with particularly high scores in attractiveness, perspicuity, usability, and simulation. The overall user experience is rated favorably, with a majority of users expressing satisfaction with the game. The high overall percentage of 91.1% indicates that the majority of participants had a positive experience while interacting with the game. These findings suggest that the game effectively engages users and provides an enjoyable and educational experience, helping to raise awareness of the upcycling concept.

5. Conclusion

In conclusion, the "Let's Upcycle" mobile application has effectively raised awareness about upcycling through an engaging game-based learning approach. The project successfully developed the mobile application and assessed user experience using the User Experience Questionnaire (UEQ). The overall high ratings indicate that the game effectively promotes upcycling awareness and enhances knowledge through its content.

However, some limitations need to be addressed. The use of built-in fonts may cause appearance inconsistencies, and hand-drawn visuals can make the game seem flat. Additionally, the game is currently compatible only with Android devices and is available only in English, posing accessibility challenges for non-English speakers. Future work will involve properly importing fonts and utilizing suitable design tools for more consistent visuals. Expanding platform compatibility and adding multilingual support will further improve accessibility. Addressing these aspects will enhance "Let's Upcycle," making it more engaging and user-friendly in promoting upcycling awareness.

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