UI/UX design for AR card game: enhancing English vocabulary learning with augmented reality

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Abstract

This study aims to develop and evaluate an Augmented Reality (AR)-based learning tool in the form of an AR Card Game to enhance English vocabulary acquisition among third-grade elementary school students, specifically on the topic of "Fruits and Vegetables." The development process employed the User-Centered Design (UCD) methodology to ensure that the user interface and user experience (UI/UX) were aligned with the cognitive characteristics and needs of the target users. The prototype, designed using Figma, integrates interactive features including 3D object visualization, audio pronunciation guides, gamified elements, and physical card-based AR interaction. Evaluation was conducted through student questionnaires, teacher interviews, and classroom observations. The results indicate that the AR Card Game was positively received. A total of 85.07% of students reported improved understanding through 3D visuals, while 89.55% found the audio helpful for pronunciation. The gamification feature achieved a mean score of 4.18 (SD = 0.73), and a one-sample t-test revealed a statistically significant difference from the neutral score (p < 0.001), confirming its motivational impact. The coefficient of variation (17.48%) indicates consistent student responses. Teacher feedback also supported the tool's effectiveness, although recommendations were made to improve navigation and enhance the evaluation component. Limitations of this study include its short-term implementation and focus on a single thematic domain. Future research is recommended to investigate long-term engagement, adaptive difficulty mechanisms, and the scalability of AR-based learning in broader curricular contexts. The findings underscore the potential of AR Card Games as effective and engaging tools for early language education in digital learning environments.

1. Introduction

The development of technology in the era of Industry 4.0 has opened many opportunities in the field of education, particularly through the use of Game and Augmented Reality (AR) technology as innovative learning media. AR is a technology that enables the integration of three-dimensional virtual objects into the real world, allowing users to interact in real-time [1]. The application of AR technology in education provides a new, more engaging, and interactive learning experience [2], while also serving as an innovative tool for teachers to support the learning process [3].

Game-based learning has also gained traction as an effective pedagogical approach. Educational games combine learning content with game mechanics, creating a fun and engaging learning environment [4], [5], [6], [7]. In the context of elementary education, AR-based educational games hold great potential, as they combine 3D object visualization with direct interaction, which has been shown to enhance motivation and conceptual understanding [8], [9], [10].

One innovation in the development of AR-based learning media is the AR Card Game, which combines physical cards with AR technology to create a more immersive learning experience. Previous studies have shown that this combination can enhance the experience of learning through play [11]. Furthermore, technology-based Educational Play Tools (EPTs), such as AR Card Games, have become relevant learning media for the needs of the digital generation. The AR Card Game merges physical card elements with AR technology to create an engaging learning experience.

However, one challenge in developing technology-based learning media is the design of the user interface (UI) and user experience (UX). Research shows that a child-friendly UI/UX design, with simple navigation and appealing visual elements, can enhance the effectiveness of learning media. Therefore, applying the User-Centered Design (UCD) method is essential to ensure that the design meets the needs of the users—in this case, elementary school students [12]. English language learning in elementary schools often faces various challenges, such as low student motivation,

monotonous teaching methods, and limited interactive learning media. The English curriculum, which includes the theme "Fruits and Vegetables," can sometimes be difficult for students to understand if presented only in textual form. On the other hand, existing learning media, such as textbooks and traditional flashcards, are no longer sufficient to meet the learning needs of students in the digital age. Therefore, an innovative AR-based educational game design is needed to help improve student interest and understanding of English vocabulary related to the theme of "Fruits and Vegetables".

Previous research has confirmed that AR technology can enhance students' visualization skills and understanding of learning material [13], [14]. However, most studies have not given enough attention to the integration of UI/UX design in the development of AR-based learning media, particularly those designed for children. Additionally, there has been limited research on the development of AR Card Games for specific themes such as "Fruits and Vegetables" in English language learning [15], [16]. Previous studies have explored various AR applications in education. Nahdiya et al. (2024) demonstrated that an AR application successfully increased young learners' interest in wildlife conservation by combining fun gameplay with educational content [17]. In physical education, AR has been proven to enhance student motivation and activity levels compared to traditional methods [18]. Meanwhile, in mathematics, the AR Card Game has been shown to improve students' spatial geometry understanding with significant learning outcomes [19]. In terms of technology acceptance and health considerations, AR games are well received, though concerns regarding costs and potential health risks have been noted by educators and parents, highlighting the need for careful consideration in their implementation [20]. During the design process, user feedback is crucial for creating educational games that are both engaging and user-friendly, meeting students' needs [21]. An effective AR interface should prioritize interactive navigation and easy-to-understand feedback [22].

In the context of UI/UX design, the User-Centered Design (UCD) approach is crucial for ensuring an optimal user experience [23], [24]. The UCD process involves users throughout the design phases, ensuring that the final product aligns with their expectations and requirements [25]. Studies show that applications designed with UCD principles significantly enhance user satisfaction, as evidenced by improved performance metrics in weather alert applications [25]. However, there is still a gap in research on how UI/UX can be optimized in AR Card Games for English vocabulary learning. The main challenges in applying AR in elementary education are app navigation, child-friendly interactive design, and an evaluation system that can be used by teachers. Therefore, this study focuses on the development of a UCD-based UI/UX design to enhance the effectiveness of AR Card Games in English language learning.

While several AR-based learning applications, such as PrismAR [11], Wildlife AR Games [17], and other generic educational AR platforms [15], [16], have demonstrated their ability to improve engagement and conceptual understanding, most of them do not comprehensively integrate key pedagogical features. Specifically, they often lack a child-centered UI/UX design approach tailored for young learners, real-time evaluation tools that support teacher involvement, and structured gamification aligned with school curricula. To highlight the novelty of this study, a comparison of key aspects across representative AR learning applications is presented in Table 1.

Table 1. Comparative Analysis of Existing AR-Based Learning Applications and This Study's AR Card Game

Aspects	PrismAR (2022) [11]	Wildlife AR Game (2024) [17]	Generic AR Learning Games [15], [16]	This Study: AR Card Game
Target Subject	Math (Geometry)	Science (Conservation)	Various (STEM, Literacy)	English Vocabulary (Fruits & Vegetables)
Target User	Middle school students	Young learners	Primary & Secondary	3rd Grade Elementary Students
Physical Interaction	Yes (Card-based)	No	Mostly digital-only	Yes (Scan physical cards and multiple cards)
Gamification	Limited scoring	Game-based but no points	Varies by app	Scoring, Challenges, Rewards
Real-Time Evaluation	Not available	Not available	Not integrated	Yes (Teacher Dashboard)
Curriculum Integration	Conceptual, math-aligned	Non-curricular	Limited	Aligned with English Curriculum
UI/UX Methodology	Conventional	Conventional	Mixed	UCD (User-Centered Design)
Audio Pronunciation Support	No	No	Rare	Yes

As shown in Table 1, the AR Card Game developed in this study uniquely combines the four critical elements: interactive AR, gamification, child-centered UI/UX, and teacher-focused evaluation tools, which are rarely found together in existing AR learning applications. This study thus contributes both practically and methodologically to the design of effective AR tools for vocabulary learning in elementary education.

This study contributes to the development of UI/UX for the AR Card Game using the UCD approach to ensure the application is user-friendly for elementary school students. Specifically, this research focuses on:

1. **Development of a child-friendly UI/UX** by providing intuitive navigation, large icons, and visually engaging elements that align with the cognitive skills of elementary school students.

2. **Integration of gamification** to enhance learning motivation by adding a scoring system, challenges, and achievement-based rewards to make learning more interactive.
3. **Implementation of an evaluation system for teachers** by developing features that allow teachers to track student progress automatically, assess vocabulary understanding, and manually set the level of difficulty adaptively through the teacher dashboard page.
4. **Refinement of AR-based interaction features** to ensure students can use physical cards to directly interact with 3D objects within the app.

With this contribution, the study aims to bridge the gap in UI/UX design for AR Card Games and ensure that AR technology can be more effectively implemented in English language learning for elementary school students.

2. Research Method

The research approach used in this study is User-Centered Design (UCD). This method was chosen because it places the needs of the users at the center of the design process, ensuring that the developed UI/UX aligns with the characteristics of elementary school students [23], [24]. Additionally, this method is more effective than other approaches, such as ADDIE or Design Thinking, because it allows for rapid iterations based on user feedback at each stage. The stages of the UCD research method are illustrated in Figure 1.
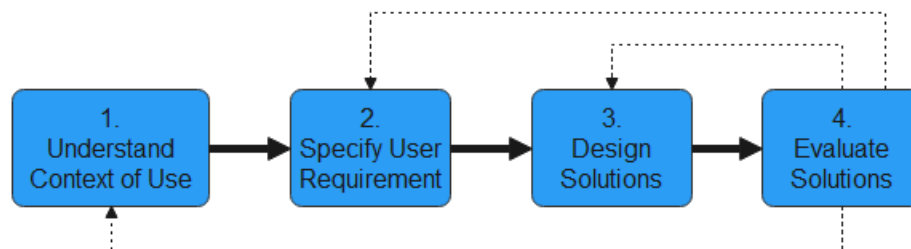

Figure 1. Flowchart of User-Centered Design

UCD consists of four main stages [26]:
1. **Understand Context of Use**: The researcher conducts interviews with teachers and distributes questionnaires to students to identify challenges in English language learning and their expectations for interactive learning media.
2. **Specify User Requirements**: Design requirements are defined based on the results of data analysis. At this stage, user needs are formulated, covering aspects such as visualization, navigation, gamification, and evaluation features for teachers.
3. **Design Solutions**: Wireframes and prototypes are developed using Figma, considering child-friendly UI/UX design principles.
4. **Evaluate Solutions**: The prototype is evaluated with elementary school students through student satisfaction questionnaires and teacher interviews to assess effectiveness and user experience. To strengthen the validation of the AR Card Game's effectiveness, this study also employed hypothesis testing. A one-sample t-test was conducted to determine whether the students' mean response to the gamification feature significantly exceeded the neutral value of 3 (on a 1–5 scale), indicating a positive acceptance of the feature.

The flowchart in Figure 1 illustrates the cyclical nature of the User-Centered Design (UCD) process. In this study, iteration was applied particularly between the 'Evaluate Solutions' and 'Design Solutions' stages. After the initial prototype testing with students and feedback from teachers, several design elements were revised, especially in terms of visual layout and navigation features to improve usability and engagement. This step reflects the core principle of UCD, where continuous refinement based on user feedback is essential to produce effective and user-friendly learning tools. This iterative step reflects the essential nature of UCD, which emphasizes user involvement and continuous refinement to ensure the resulting interface is both usable and effective for the target audience.

The research subjects in this study were third-grade elementary school students from Kuningan, West Java, with a total of 67 students from two classes in one school. These sixty-seven third-grade students were selected based on inclusion criteria: they had already learned the vocabulary related to "Fruits and Vegetables" and had basic skills in using digital devices (tablets/smartphones). The third-grade students served as the participants in this study, while the English language teachers provided feedback on the relevance of the content and learning media. Data collection in this study was conducted through student questionnaires, teacher interviews, and direct classroom observations. This approach ensures that the resulting UI/UX design is not only intuitive and child-friendly but also aligns with curriculum needs.

2.1 Research Process
The research process followed the UCD stages, which included:
1. **Stage 1:** Understanding the Context of Use

At this stage, the researcher conducted interviews with teachers to explore the needs of English language learning, specifically focusing on the "Fruits and Vegetables" theme. The interviews aimed to identify the challenges teachers face in teaching vocabulary and their preferences for existing learning media [27]. The interview questions were prepared with reference to a needs analysis approach in the development of learning media, aiming to collect relevant and accurate data [28], [29]. The data collected will be used to design AR game concepts and features that suit the needs of teachers and the characteristics of elementary school students. The list of interview questions prepared by the researcher is provided in Table 2.

Table 2. Interview Questions for Teachers

No	Interview Questions	Descriptions	Goals
1	What are the main challenges you face when teaching English, particularly vocabulary related to fruits and vegetables, to third-grade students?	To identify challenges encountered by teachers when teaching English vocabulary.	To understand the obstacles that need to be addressed in designing learning media.
2	What learning media do you currently use to teach this theme?	To understand the learning media currently used by teachers for the fruits and vegetables theme.	To identify gaps between the existing learning media and what is needed.
3	Do you feel that the current learning media are effective? Why or why not?	To assess the effectiveness of the existing learning media from the teachers' perspective.	To evaluate the need for innovation in technology-based learning media.
4	In your opinion, can technology like Augmented Reality (AR) help students understand vocabulary better? If so, how should such media be designed?	To explore teachers' opinions on the potential of AR technology for learning.	To ensure that the design of the AR Card Game aligns with students' learning needs.
5	What features do you think are most important in technology-based learning media for elementary school students?	To identify the technological features that teachers consider essential for elementary students.	To design features that align with students' preferences and needs.

In addition to conducting interviews with teachers, the researchers also distributed questionnaires to students to identify challenges in understanding the vocabulary of "Fruits and Vegetables" and assess their preferences for learning media design. The questionnaire was based on a needs analysis approach that emphasizes the importance of understanding students' learning needs, including their learning interests, experience with educational technology, and desired features in interactive learning media. As stated by Kaskani et al. (2021) [30], a comprehensive needs analysis can be helpful in designing learning materials that are appropriate to the context and needs of students. The evaluation methodology for the AR Card Game is based on the validated User-Centered Design (UCD) framework, which emphasizes user involvement. Structured questionnaires, developed from a comprehensive needs analysis and validated through existing studies, are used to gather relevant feedback on user experience and effectiveness. This systematic approach ensures a thorough assessment of the application's impact on learning outcomes and user satisfaction. The design of the student questionnaire is presented in Table 3.

Table 3. Questions List for Students' Questionnaires

No	Questionnaire Questions	Description	Goals
1	Do you enjoy learning English?	Identify students' interest in learning English.	Understand whether students have sufficient initial motivation to learn English.
2	How do you currently learn English?	Understand the learning methods currently used by students.	Determine a relevant approach based on methods familiar to students.
3	Do you find English vocabulary related to fruits and vegetables difficult to understand?	Assess students' level of difficulty in understanding vocabulary related to fruits and vegetables.	Assess the need for more effective learning media for specific vocabulary.
4	Have you ever used technology-based educational apps or games for learning?	Identify students' experiences with application- or game-based learning technologies.	Evaluate students' readiness to use technology as a learning medium.
5	What features do you find most interesting in learning media?	Explore students' preferences for engaging features in learning media.	Assist in designing the UI/UX with features that match students' preferences.

The insights gained from the questionnaire in Table 3 provide a clear understanding of students' interest in learning, study habits, vocabulary challenges, familiarity with educational technology, and preferences in media design. These findings are essential for developing a targeted English learning application that meets student needs. By integrating relevant content, engaging features, and an accessible interface, the application aims to increase student engagement and enhance vocabulary acquisition, particularly in areas such as fruits and vegetables. This evidence-based approach ensures that the learning media is both effective and appealing. To conclude, Table 4 presents a summary of the user needs analysis, derived from both teacher interviews and student questionnaires.

Table 4. Analysis of Student and Teacher Needs Based on Questionnaires and Interviews

Aspect	Students' needs	Teachers' needs
Learning challenges	Difficulties in understanding vocabulary related to fruits and vegetables.	Students struggle to understand the material without strong visual aids.
Currently used media	Learning videos and textbooks are predominantly used.	Textbooks, flashcards, and learning videos are commonly used.
Media effectiveness	Some students find the current media boring.	Current media is less effective in increasing student engagement.
Desired features	3D animations, scores/challenges, and engaging visuals.	Engaging visuals, simple navigation, and gamification are preferred.
AR technology opinion	Most students support technology-based media.	Teachers are optimistic that AR can enhance students' understanding and motivation.
Methods of Learning Evaluation	Through interactive games and simple quizzes.	Vocabulary tests, observations, and group discussions are used for evaluation.
New media suggestion	A fun and easy-to-use game.	Media that combines AR interaction with educational elements is recommended.

The outcomes of this stage form the basis for designing the UI/UX of the AR Card Game. With user needs identified, the subsequent step is to define user requirements to guide the prototype development process.

2. Stage 2: Specify User Requirements
After gathering information from the previous process, the researcher formulated the user requirements. This step aims to ensure that the UI/UX design of the AR Card Game aligns with users' needs, expectations, and preferences. This user needs analysis is based on a needs analysis approach that emphasizes the importance of understanding students' learning needs, including their learning interests, experience with educational technology, and desired features in interactive learning media. As stated by Kaskani et al. (2021), a comprehensive needs analysis can be helpful in designing learning materials that are appropriate to the context and needs of students [30]. The compiled user requirements are presented in Table 5.

Table 5. User Requirements

Components	User Needs	AR Card Game Implementation
Visualization	Students need engaging 3D animations to understand vocabulary.	Provide 3D visualizations of fruits and vegetables with bright colors and interactive animations.
Audio Explanation	Both teachers and students want media that provides audio explanations for vocabulary.	Include audio with correct English pronunciation for each fruit and vegetable.
Gamification	Score elements and challenges to boost student motivation.	Add features for scoring, challenges, and rewards based on student achievements.
Navigation	Simple navigation to ensure ease of use for elementary school students.	UI design with large icons, one-level navigation, and clear visual guides.
AR Interaction	Learning media that combines physical cards and AR technology.	Feature for scanning physical cards (Fruits and Vegetables cards) to display 3D objects of fruits and vegetables in real-time on the device screen.
Teacher Evaluation	Teachers need a way to directly evaluate students' understanding.	Provide a learning progress report feature, such as a list of vocabulary learned and students' final scores.
Contextualization	The media should be aligned with the English curriculum on the theme of "Fruits and Vegetables."	Learning content aligned with vocabulary material from the English curriculum for elementary school students.

Table 5 summarizes how the AR Card Game addresses the essential needs of both students and teachers. Through features such as 3D visualizations, audio narration, gamification, intuitive navigation, and curriculum alignment, the media provides an engaging and effective tool for vocabulary learning. With the user requirements clearly defined, the next stage is to proceed to the Design Solutions phase.

3. Stage 3: Design Solutions
The Design Solutions phase focuses on developing wireframes and UI/UX prototypes that align with the User Requirements that have been formulated. During this stage, wireframes and prototypes were created using Figma, allowing for iterative testing and development before final implementation. Each wireframe developed reflects the visual aspects, navigation, gamification, and AR integration designed to help elementary school students understand English vocabulary. Below is a description of the wireframe created based on the user needs.
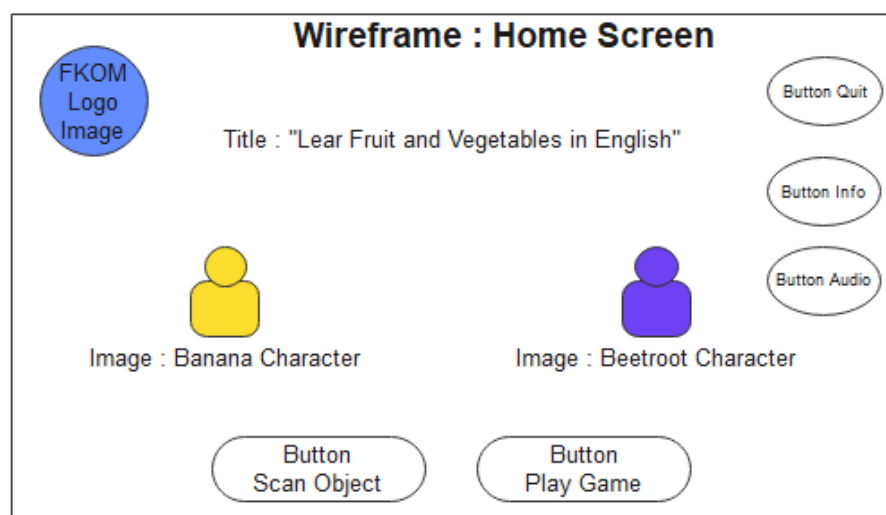
a.   Wireframe of the Home Screen

Figure 2. Wireframe of the Home Screen

The main screen of the application appears after the user successfully logs in. This design is created to be attractive and child-friendly, featuring cute characters (Banana and Beetroot) that greet the user. The "Scan Object" button is used to scan physical cards using the camera. The "Play Game" button is for starting the interactive and vocabulary-based educational game. On the right side of the screen, there are secondary navigation buttons: Quit Game, Info, and Audio. These buttons facilitate easy navigation, provide additional information about the application, and allow users to control the audio, making navigation more convenient.

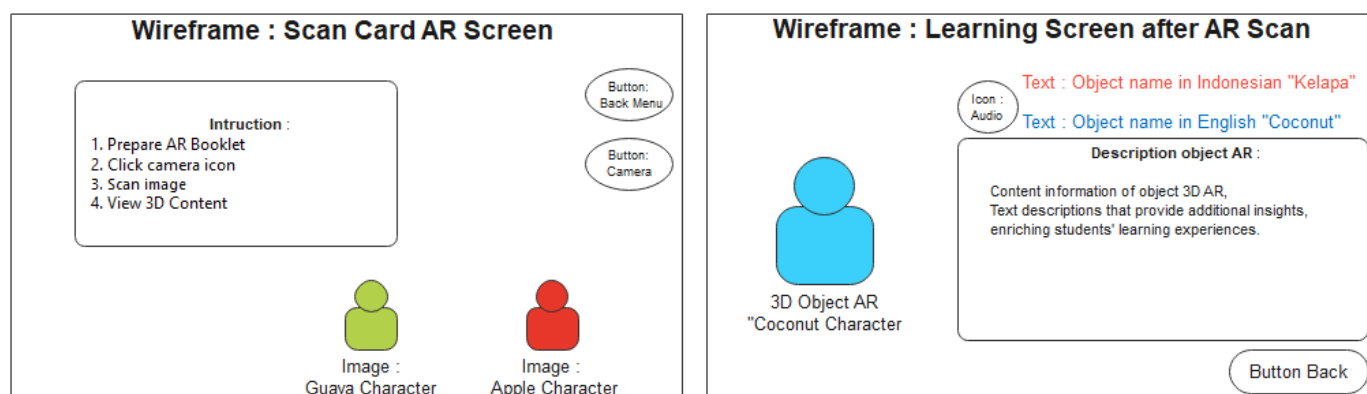b.   Wireframe of the AR Scan dan Learning Screen

Figure 3. Wireframe of the AR Scan and Learning Screen

The AR Scan wireframe is designed as the main guide for users before starting the AR card scanning process. The center of the screen displays an instruction panel, which contains step-by-step usage instructions. The instructions are presented in a clear layout to ensure easy understanding and smooth navigation.

The learning screen wireframe is designed to display educational information after the user scans the AR card. On the left side of the screen, there is a visual representation of the object, helping to associate the vocabulary with a visual cue. At the top of the screen, the main vocabulary is shown, with the name of the fruit in both Indonesian ("KELAPA") and English ("COCONUT"), using red and blue colors to emphasize the language distinction. An audio button is available, allowing students to listen to the pronunciation of the vocabulary in English, helping them improve their listening skills. The bottom-right section of the screen contains a text description that provides additional insights, enriching the student's learning experience. This design harmoniously integrates visual, audio, and text elements to ensure an interactive, engaging, and immersive learning experience for students.
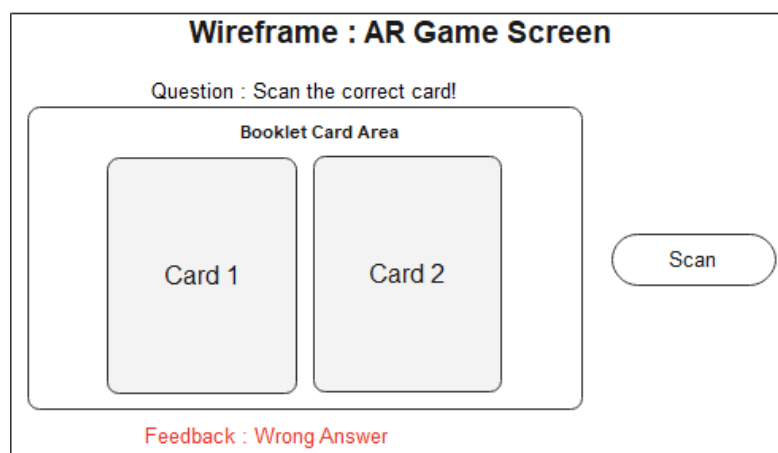
c.   Wireframe of the AR Game Screen

Figure 4. Wireframe of the AR Game Screen

This wireframe integrates gamification into the AR Card Game, where students scan fruit or vegetable cards to answer questions. The instruction "Scan the correct card!" appears at the top of the screen, providing direct guidance. After scanning, real-time feedback is displayed: "Correct Answer" (in green) or "Incorrect Answer" (in red). This design ensures an interactive, engaging, and challenge-based learning experience.
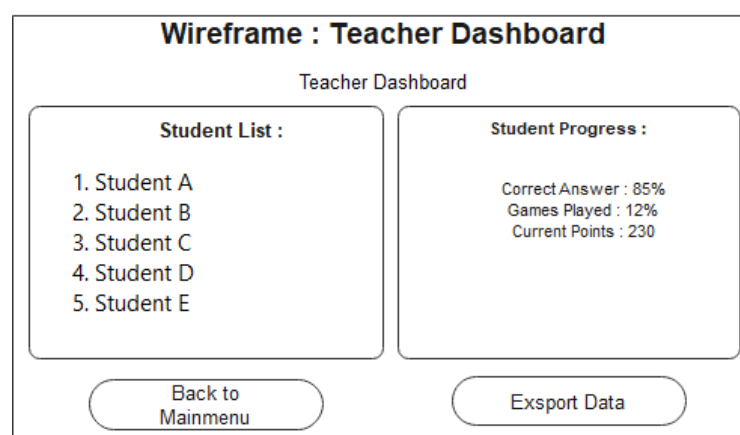
d.   Wireframe of the Teacher Dashboard

Figure 5. Wireframe of the Teacher Dashboard

This wireframe is designed to support teachers in monitoring the progress of students using the AR Game application. The Teacher Dashboard provides two main panels: the Student List Panel and the Student Progress Panel, which make it easy for teachers to access important information related to students' learning activities. After designing the wireframe, the next step is to develop an interactive prototype that integrates AR elements, gamification, and Educational Game Tools (EGTs).

This prototype is developed based on the User Requirements and is designed using Figma to visualize the UI/UX interactively before the final implementation. Below are the key components in the development of the AR Card Game prototype:
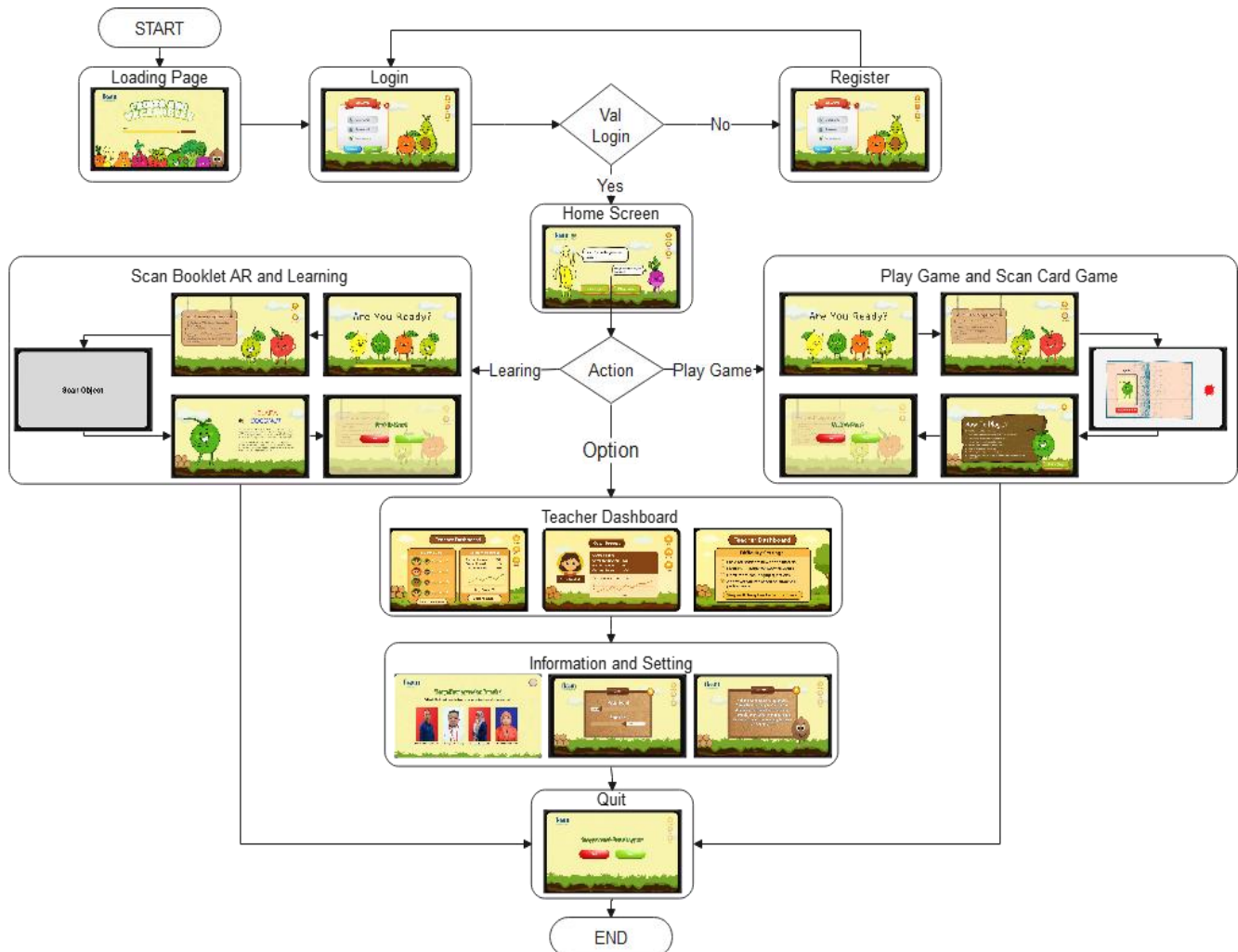
a.   UI/UX Flowchart for AR Card Game

Figure 6. UI/UX Flowchart for AR Card Game

This flowchart illustrates the user navigation flow in the AR Card Game, starting from the landing page to the Login/Register screen. Once the user successfully logs in, they are directed to the Home Screen, which provides two main options:" AR Scan Booklet & Learning" or "Play Game & Scan Card Game."

b.   Prototype of the Home Screen and Navigation Settings

Figure 7. Prototype of the Home Screen and Navigation Settings

The home screen design is created based on the need for a simple yet engaging visual, featuring 3D animations of a banana and beetroot to capture students' attention. It also includes buttons for scanning objects and playing the game, with bold colors for easy identification. The navigation settings, located in the top right corner, allow users to control audio and access necessary information within the app. The design uses soft colors to ensure a comfortable viewing experience while accessing information and adjusting settings.

c. Prototype of the AR Scan Booklet and Learning
d.

Figure 8. Prototype of the AR Scan Booklet AR and Learning

On this page, when the user selects "Scan AR," they will be provided with a guide on how to use the app. After scanning the provided AR booklet, the app will display a learning page with the name of the fruit or vegetable in both Indonesian and English, using large heading fonts. It will also feature 3D animations of the fruit and vegetable objects, along with audio navigation for pronunciation in English. Additionally, there will be descriptions of the fruits and vegetables, offering a comprehensive learning experience.

e. Prototype of the AR Play Card Game

Figure 9. AR Play Card Game

The Play Game design incorporates gamification with a card-matching game, where users match physical cards with questions in the app. If the answer is correct, the user earns points. In the design navigation concept, users are provided with information before starting the game. The innovative concept is the integration of physical card games with AR technology, creating an interactive and engaging learning experience.

f.　Design of the Teacher Dashboard

Figure 10. Teacher Dashboard

The Teacher Dashboard (Figure 10) provides real-time monitoring of student progress. It displays a list of students along with summary data such as correct answers, games played, current points, and performance graphs. Teachers can also export reports for further analysis. When a student is selected, a detailed view shows each student's performance over time, helping teachers identify trends and learning needs. Currently, the difficulty level is manually adjusted by the teacher, but the system is designed for future integration of adaptive algorithms using deep learning, allowing for personalized difficulty adjustments based on student performance.

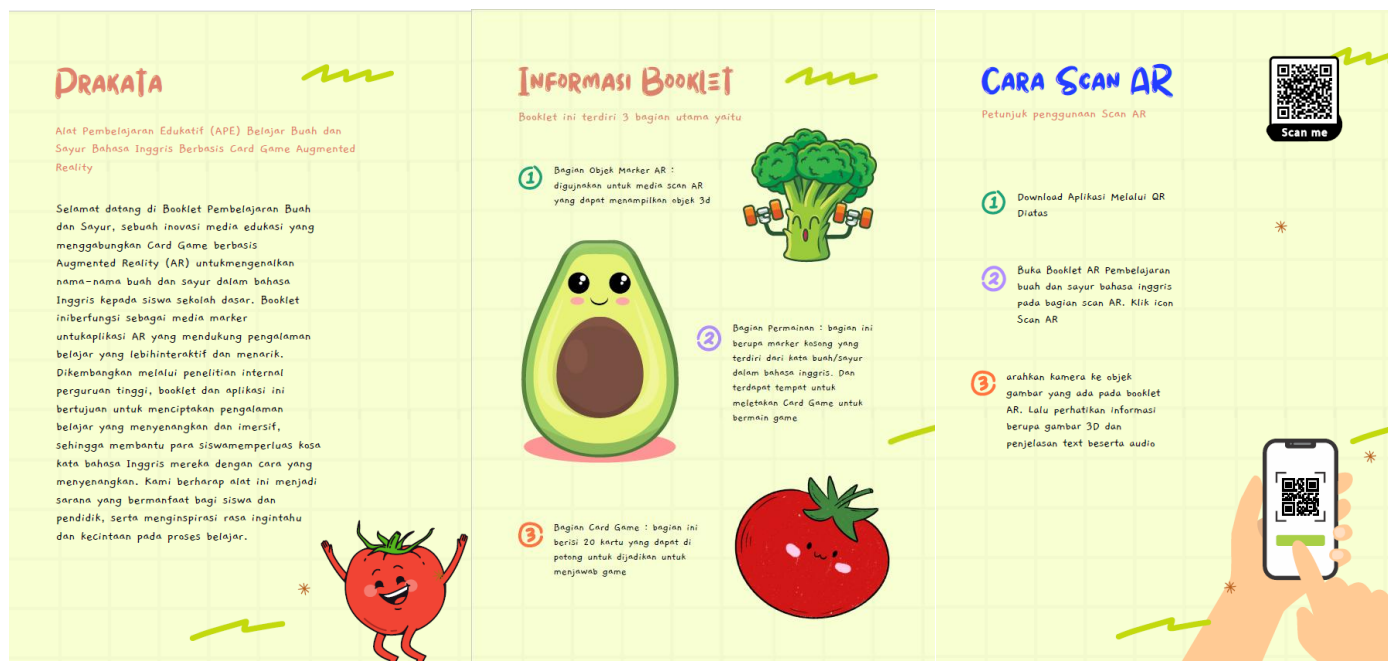g.　Design of the AR Card Game Booklet

Figure 11. Design of the AR Card Game Booklet

This booklet is an innovative AR-based Educational Game Tool (EGT) designed to meet the needs of students who desire an interactive, technology-based learning medium, featuring bright colors, engaging characters, and simple fonts tailored to the target users.

h.   "Fruits and vegetables" Game Card Design

Figure 12. Design of the Fruit and Vegetable Game Cards

The design of the fruit and vegetable game cards, as part of the booklet, serves as an EGT medium. These game cards are created to meet the users' needs for an interactive and enjoyable learning tool, combining fruit and vegetable cards with the concept of an interactive conventional game.

4. Stage 4: Evaluate Solutions

The developed prototype was then evaluated with a small group of elementary school students. The trial was conducted during a learning session to assess the effectiveness of the learning media. During this process, data was collected through questionnaires to measure student satisfaction with the UI/UX design. Additionally, interviews with teachers were conducted to gather feedback on the media's effectiveness in supporting English language learning.

The design and components of the evaluation questionnaire created by the researcher for students are shown in Table 6. This questionnaire aims to evaluate the students' experience with the AR Card Game, focusing on aspects such as visualization, navigation, gamification, and the effectiveness of learning.

Table 6. Designs and Components of the Evaluation Questionnaire of the Prototype for Students

Components	Questions	Goals
3D Visualization	Did the 3D animation of fruits and vegetables in the game help you understand the vocabulary better?	Assess how much the 3D visualization helps students understand vocabulary concepts.
Audio Description	Did the sound or audio in the game help you learn the pronunciation of the vocabulary?	Measure the effectiveness of the audio feature in helping students master vocabulary pronunciation.
Gamification	How enjoyable is the scoring and challenge system in this game?	Evaluate whether the gamification elements increase students' motivation to learn.
Navigation	Did you experience any difficulty navigating this game?	Determine if the navigation within the game is easy enough for elementary school students.
AR Interaction	Do you feel that the physical card scanning feature (AR) helped you understand the lesson better?	Measure the impact of using the AR feature on improving students' learning experiences.
Effectiveness of Learning	Do you find it easier to understand English vocabulary after using this game?	Assess whether this application enhances students' understanding of English vocabulary.
Curriculum Contextualization	Is the information in the game aligned with the English lessons at your school?	Evaluate how well the material in the game aligns with the curriculum used in the school.

The results of this questionnaire were analyzed using descriptive statistical methods, including student satisfaction percentages, average scores, and standard deviations, to gain insights into students' acceptance of the application.

The design of the questions and components of the prototype evaluation interview for teachers, which have been prepared by the researcher, are presented in Table 7. The interviews with teachers aim to gain insights into the effectiveness of the game from the instructor's perspective and to identify areas that still require improvement.

Table 7. The Design and Components of the Prototype Evaluation Interview Questions for Teachers

Components	Questions	Goals
3D Visualization	Do you think the 3D visualization in this game helps students understand vocabulary? Why?	Assess the extent to which 3D visualization supports students' understanding of vocabulary.
Audio Description	How effective is the audio feature in helping students learn English vocabulary pronunciation?	Analyze the effectiveness of audio in enhancing students' listening and speaking skills.
Gamification	Do the gamification elements (scores, challenges, rewards) increase student motivation to learn?	Evaluate the role of gamification in increasing student motivation to learn.
Navigation	What do you think about the ease of navigation in the game for elementary students? Does it need any improvement?	Assess whether the game's navigation is intuitive enough for elementary students or if improvements are needed.
AR Interaction	How relevant is the physical card scanning feature (AR) to the students' learning needs?	Determine the relevance of using AR technology to support students' learning.

Teacher Evaluation	Does the learning outcome report feature help you evaluate students' understanding? If not, what could be improved?	Evaluate whether the teacher evaluation feature in the game is helpful in assessing students.
Curriculum Contextualization	How well does the learning content in the game align with the elementary school English curriculum?	Assess the alignment of the game's content with the English curriculum used in schools.

Feedback from teachers were categorized and analyzed using thematic analysis to identify patterns in their perceptions of the effectiveness of this learning media.

3. Results and Discussion

This chapter presents the research findings on the use of the AR Card Game as an English learning medium for elementary school students. The study aims to measure the effectiveness, user experience (UI/UX), and the impact of gamification in enhancing students' vocabulary comprehension. The results obtained from student questionnaires and teacher interviews were analyzed to evaluate how well the application meets user needs and aligns with learning objectives.

3.1 Result
3.1.1 Students' Questionnaire Result

Based on the questionnaire results given to 67 third-grade elementary school students, it was found that many students responded positively to the use of the AR Card Game in learning English vocabulary.
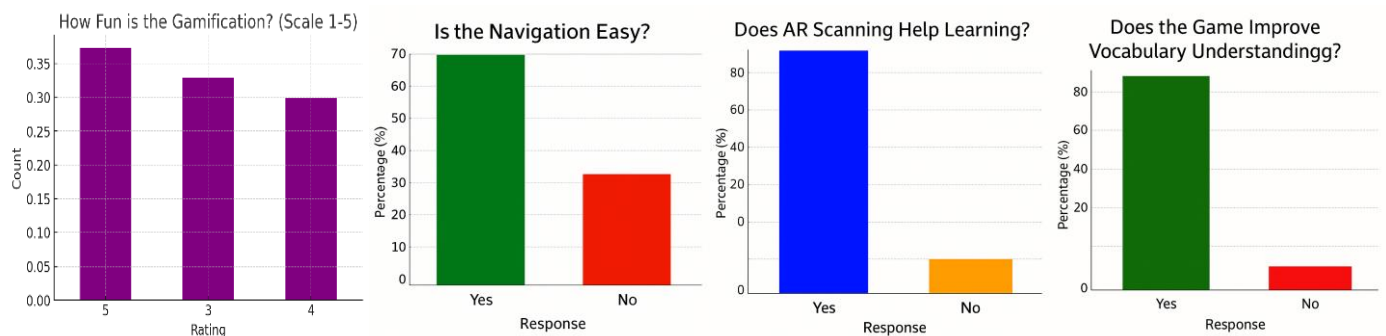

Figure 13. The Visualization of Students' Questionnaire Result

Figure 13 displays the results of the student questionnaire on the AR Card Game. Most students rated the gamification as enjoyable, with scores mainly between 4 and 5 on a 5-point scale. They also found the navigation easy, indicating that the interface was well-suited for elementary learners. Over 80% agreed that AR scanning enhanced their learning and improved vocabulary comprehension. These findings suggest the AR Card Game is both engaging and effective in helping students learn English vocabulary. The results of the prototype evaluation by students are presented as percentages in Table 8.

Table 8. Results of the Prototype Evaluation by Students

Category	Percentage (%)
Helped by 3D visualization	85.07
Audio helps pronunciation	95.52
Easy navigation	71.64
AR helps comprehension	91.04
Vocabulary is easier	88.06
Based on curriculum	74.63

Based on the visualization of the questionnaire results in Figure 13 and Table 7, 85.07% of students stated that the 3D visualization feature helped them understand vocabulary better. Additionally, 89.55% of students acknowledged that the audio feature assisted them with pronunciation. In terms of user experience, 80.60% of students felt that the app's navigation was easy to use, while 83.58% stated that the AR card scanning feature helped them better understand the lesson.

Table 9. Gamification Analysis

Category	Mean	Standard Deviation	The Average of satisfaction index	Coefficient of Variation (%)
The Excitement of Gamification (1-5 Scale)	4.044776	0.842665	4.044776	20.83343

Based on the analysis of the gamification excitement feature in the AR Card Game in Table 9, the average gamification excitement score is 4.18 on a scale of 1-5, indicating that students enjoyed this feature during the learning process. The standard deviation of 0.73 shows that most students provided similar responses, with scores ranging from 3 to 5. Additionally, the Coefficient of Variation (CV) of 17.48% indicates that students' responses were consistent, suggesting that the gamification in the AR Card Game was well received. However, to further enhance the learning experience, it is recommended to add more variation in the challenges and reward systems to motivate students even more, making the process of learning English vocabulary more interactive and enjoyable.

Table 10. T-test Statistics

Variable Tested	Hypothesized Mean	Sample Mean	Std. Deviation	t-value	p-value	Conclusion
Gamification Rating	3.00	4.18	0.73	12.61	<0.001	Significantly Higher

A one-sample t-test was performed to validate whether the average rating for the gamification feature (mean = 4.18, SD = 0.73) was statistically significantly higher than the neutral benchmark value of 3. The result, presented in Table 10, showed a t-value of 12.61 with $p < 0.001$, indicating a statistically significant positive perception among students. This confirms that the gamification component of the AR Card Game effectively enhanced student engagement and learning motivation.

3.1.2 Teacher Interview Result

From interviews conducted with two elementary school English teachers, it was stated that 3D visualization is very helpful in capturing students' attention and making learning more interactive.

Table 11. Teacher Evaluation Result

Category	Average (%)
Average Rating for 3D Visualization	4.5
Average Rating for Audio Effectiveness	5
Gamification Increases Motivation	100
Easy Navigation	50
AR helps understanding	100
Helped by evaluation feature	50
Align with curriculum	100

Based on Table 11, the average score given by the teachers for this feature is 4.5 on a scale of 1 to 5. Additionally, the audio feature is also considered highly effective in helping students understand vocabulary pronunciation, with an average score of 4.6.

3.1.3 Data analysis and discussion

Based on the comparison between the results of the student questionnaires and teacher interviews, it can be concluded that the AR Card Game has a positive impact on improving students' vocabulary understanding. The statistical results show that over 80% of students benefited from the AR, audio, and gamification features. However, there are still some challenges in classroom implementation, particularly in the areas of navigation and evaluation features. Statistical interpretation and impact can be seen in Table 12.

Table 12. Effect and Interpretation

Category	Result/ Description
Mean (Gamification Score Average)	4.18: It indicates that the gamification feature is quite liked by the students.
Standard Deviation)	0.73: Showing students' variety answers.
Coefficient of Variation	17.48%: Showing students consistently answered.
Increase of Motivation	Most students are more motivated to learn English vocabulary with the AR Card Game.

More interesting Interaction	The 3D visualization and audio features make it easier for students to understand vocabulary concepts.
Navigation that needs improvement	Some students still have trouble in operating the application.
Lack of Teacher Evaluation Features	The teacher feels that the evaluation system in the app is not sufficient in assessing students' progress.

3.2 Discussion

Despite the positive outcomes observed in this study, several limitations must be considered. First, the research was limited to the vocabulary theme "Fruits and Vegetables" for third-grade elementary school students, which may not generalize to other language topics or age groups. Second, the trial was conducted in a single school with a relatively small sample, limiting the broader applicability of the findings.

Future research should consider expanding the scope of vocabulary themes and including students from various regions and grade levels. Further developments can also explore the integration of adaptive learning mechanisms using artificial intelligence (AI) to personalize content according to student performance. Moreover, longitudinal studies are recommended to assess the long-term effectiveness of AR-based learning tools on vocabulary retention. Lastly, efforts to align the game more comprehensively with the evolving national curriculum, such as Curriculum Merdeka, can enhance the relevance and sustainability of the application.

4. Conclusion

The research findings indicate that the AR Card Game is effective in enhancing students' learning experiences through 3D visualization, interactive audio, gamification, and AR-based interactions. Of the 67 students, 85.07% found the 3D visualization helpful, while 89.55% felt that the audio feature assisted with vocabulary pronunciation. Gamification received an average score of 4.18 out of 5, with a standard deviation of 0.73, indicating that students enjoyed game-based learning. The results of teacher interviews confirmed the effectiveness of 3D visualization and audio in increasing student engagement, with average scores of 4.5 and 4.6, respectively. However, challenges were identified in navigation and evaluation features, which still require refinement. The coefficient of variation of 17.48% indicates consistent student responses, suggesting that the features within the game were well received. Overall, the AR Card Game proves to be an engaging and effective learning innovation for elementary school students' English vocabulary. With improvements to navigation and evaluation, this application has the potential to be more widely adopted in future technology-based learning systems.

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