Development of an Augmented Reality Based Educational Game to Aid Elementary School Learning Using Scrum

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Abstract—To comply with health protocols during the COVID-19 pandemic, studies were conducted online. This has had a significant impact on students' motivation to learn, particularly among elementary school children. This study aims to produce an educational game with the theme of science-based augmented reality on Android devices to aid elementary-level students in their studies. By using the Augmented Reality system, students will be able to engage and interact with a 3D model of the material to be explained. The data collection and game design research method was used by implementing Scrum in the development process. This study used Scrum roles such as Product Owner, Scrum Master, Project Manager, and Development team. This study resulted in the development of an interactive augmented reality app that has successfully increased user's enthusiasm for learning. Students' interest in learning science subjects has also increased as a result of the application. This research concludes with the successful development of an augmented reality-based application on Android devices that includes quiz components and augmented reality.

Keywords— Augmented reality, Android devices, Educational game, Scrum

I. INTRODUCTION

With time, science and technology have progressed to previously unimaginable developments. This rapid and never-ending development has undoubtedly had a tremendous impact on the livelihoods of us humans. An epitome of this is how the internet has become a key need for everyday living, from social to educational requirements [1].

In times of the COVID-19 pandemic [2], face-to-face learning for students was suspended, and instead, studies were conducted online to comply with health protocols. This condition substantially impacted kids' learning patterns and lowered their motivation to learn, particularly among elementary school children.

Even though there are other alternatives to assist online learning, it cannot be denied that using video conferencing has not been as effective as traditional classroom learning. This is because the online learning process is greatly influenced by the learning environment and the characteristics of each student individually. According to

Nakayama, the success rate of online learning has not met expectations nor produced good results [3].

The ineffectiveness of online learning is proven by students' lack of comprehension, which prompted Indonesia's Ministry of Education to drastically reduce and simplify the Basic Competencies used [4].

According to one study [5], the use of interactive media for educational games scored 79.64% in feasibility, 88.87% in practicality, 92.72% in interest, and 85.05% in students' activeness. This study was conducted using the Research & Development method, with the subjects of study being 26 fourth-grade students and a teacher from Drenges 1 Kertosono Elementary Public School. Based on those findings, it is possible to conclude that the use of interactive media in educational games has a significant impact on students' learning outcomes.

Thus, this study will be focused on developing an educational game for learning fundamental natural sciences. Students will be able to engage and interact with an augmented reality model of the material to be explained. A quiz system will be implemented to assess the student's comprehension of the materials and to assist teachers by providing new references for student evaluation.

II. LITERATURE REVIEW

A. Introduction to Augmented Reality and Educational Games

Augmented reality (AR) [6] is a technology that projects computer-generated virtual information (e.g. text, images, models, videos, 3D models) into the physical world. Augmented reality is categorized into marker-based AR, location-based AR, superimposition AR, markerless AR, and projection-based AR [7].

A game [8] is an activity that relieves boredom by relying on strategy and thinking to interact with and resolve conflicts with deliberately engineered systems [9]. Action, adventure, puzzle, role-playing, simulation, and strategy are the various types of games.

The term "game genre" refers to a brief category that describes a game's storyline and influences the story structure, character depth, and other storytelling elements. The most common game genres are crime, fantasy, mystery, horror, drama, and science fiction.

An educational game, also known as game-based learning, is a game category with specific learning objectives or competency tests. This type of game tries to strike a balance between learning and playing. Game-based learning differs from gamification in that the subject's activities are redesigned using artificial conflicts and game rules in game-based learning [10].

The following are some of the advantages of educational games:

- Motivation

  Educational games are designed with appealing features to motivate and entice users. These features include points, leaderboards, badges, rewards, and even game mechanics and activities.

- User Involvement

  Educational games are extremely beneficial for learning because they provide numerous ways for users to be involved and engaged.

- Adaptation

  Educational games can simulate a specific situation for the user. This can be related to the user's knowledge, perception, emotions, and so on.

B. Augmented Reality application in Education

In 2020, a study developed an augmented reality application for biology education. This study aimed to improve biology learning performance by enabling students to interact with 3D models of animal anatomy and physiology. The result showed that the game increased the students' success in biology and motivation to learn. The study concluded that the use of augmented reality in education is promising and beneficial [11].

Another study [12], conducted in 2020, developed a mobile augmented reality game called EduPark. This study sought to investigate the possibility of learning beyond traditional classroom environments. This study attempted to assess the educational value of mobile AR games by combining mobile devices, augmented reality, and game-based learning in an educational context. According to the findings of this study, students who used the EduPARK application strongly agreed that using educational apps as an interactive learning medium can help the learning process. This study, however, was conducted outside of the school learning environment with a diverse group of participants. As a result, it begs the question of whether interactive educational applications could be used effectively in elementary school teaching and learning.

In 2015, a study [13] tried to implement mobile augmented reality in Vocational Education and Training (VET) called Paint-cAR. This study used a marker-based mobile AR application to help students learn how to repair car paint. This study shed light on how to tailor AR applications to the specific educational needs of students in VET institutions.

C. Agile

Agile is a software development methodology that implements four values in varying ways and relies on them to guide the development and deployment of functional and high-quality software. The four values of the Agile Manifesto are as follows:

1. People and their interactions, as opposed to tools and processes
2. Software that is supported by extensive documentation
3. Customer participation in contract negotiations
4. Respond to changes by sticking to the plan

The first value emphasizes collaboration and communication; teams create software rather than tools. Every team member must collaborate effectively through productive interactions when developing a project. The second value refers to how long it takes to create documentation. This value emphasized that the primary goal of software development is to create software rather than documents. The third value explains how the most important aspect of developing a successful project is collaborating with the customers. Finally, the fourth value implies that the software plan must be adaptable. There must be room for changes to respond to any circumstances, or the project plan will become obsolete. According to the four Agile Manifesto values, the team must be adaptable in responding to changes in the upcoming development steps[14].

Scrum is an agile framework that is used exclusively by more than 58% of companies, while 18% incorporate it with other framework methods. Sprint is the basic unit of work in Scrum that is executed to produce improvements to the product to be delivered. To maintain the flexibility and predictability of Scrum, sprints are typically short (lasting for one to four weeks).

To manage requirements and track the progress of a project, Scrum relies on three key artifacts: Product Backlog, Sprint Burndown Chart, and Sprint Backlog. Scrum uses several iterative meetings, such as the Daily Scrum (Standup), Review and Retrospective meetings, and Sprint Plannings to formalize this process. Although Scrum was introduced long before the Agile Manifesto, it still adheres to the documents' agile principles and values [15].

D. Usability Testing

Usability testing is a process to determine whether a user can easily use an application, how efficiently and effectively an application can assist the user in achieving their goal, and whether the user is satisfied with the application.

This study used five evaluation values to test the application's usability, namely:

1. Learnability

   How long does it take for the user to be able to properly use the application?

2. Efficiency

   How long does it take the user to figure out how to use the application?

3. Errors

How many and what kinds of mistakes did the user make while using the application?

4. Memorability

How well does the user recall the app's functions after using it?

5. Satisfaction

How satisfied are the users when using the application?

III. RESEARCH METHODOLOGY

A. Data Collection Method

The data for this study were gathered using questionnaires, literature reviews, and interviews. Offline and online questionnaires were distributed to target users of the educational game, namely teachers, students, and parents. These questionnaires asked about game satisfaction, criticism, and suggestions. Using the Literature Study method, the author researched relevant theories through books, journals, theses, and other references. Online and in-person interviews with elementary school students and teachers were also conducted.

This study was divided into eleven critical phases: problem statement determination, game concept development, data collection, literature review, game development, game and data analysis, game testing and improvement, usability testing, evaluation result, game release, and game evaluation.

B. Comparison Analysis

Assemblr Edu is a similar application that allows students and teachers to gather in the same virtual classroom to study materials using 3D AR models. This app uses the markerless AR method and is targeted at students of all ages.

Curiscope Virtual-Tee is an augmented reality educational app for human anatomy that works by scanning a special T-shirt. This app takes a similar approach to AR as our app ARIPA, using marker-based AR with the T-shirt as the marker. Because this app focuses on human organs and their functions, it is appropriate for people of all ages.

Experience Real History is an AR history educational application that can display interactive and accurate historical reenactments. Using marker-based AR, custom-made cards, such as maps of historical events and cards of historical figures, can be scanned by users to show a 3D model of accurate reconstruction of historical events.

C. Scrum Design

In this study, the researchers' role was divided into four major roles: product owner, project manager, scrum master, and development team.

The Product Owner ensures the quality of the product, establishes the backlog and priorities, and strategizes the decision-making process

The Scrum Master oversees the product's progress and ensures that the team understands the purpose and scope of the product. The Scrum Master is responsible for the daily stand-up meetings, sprint planning, and sprint retrospectives.

The Project Manager ensures that all members complete their tasks on time for each Sprint by defining the scope of the Sprint and estimating the work duration.

The Development Team carries out the product owner's backlog of tasks.

IV. RESULTS AND DISCUSSION

A. The Scrum Process

This research implemented the scrum roles concept, with each author taking on two roles in the scrum process. Because the project had few stakeholders, the research was limited to one project manager, one product owner, one scrum master, and three development teams.

Every Sprint, daily meetings are held to assess the progress of each team member. The meetings are held once a week via WhatsApp to discuss and resolve the blockers and issues that each member encounters while working on the task.

Sprint Reviews are held to discuss the backlog and the previous Sprint results. This is done to determine whether the previous Sprint's backlogs were completed successfully. Sprint reviews can result in a continuous backlog, in which the backlog is still being worked on even if the Sprint has changed. This is because some backlogs are more complex and require more time.

Sprint Retrospectives are held to further evaluate what was done in the previous Sprint and how each member's performance can be improved.

Sprint planning sessions are held to determine which backlog items will be worked on in the next Sprint, what will be accomplished at the end of a sprint, and how to achieve it.

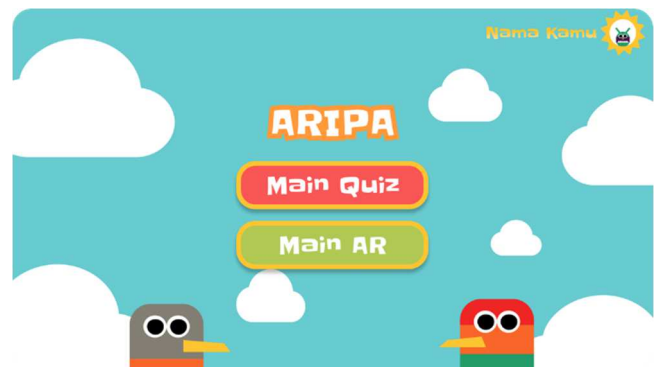#### B. High Fidelity Design Result

Fig. 1. Prototype of the Main Menu page

Fig. 1 depicts the main menu page in ARIPA, where users can select between two modes: quiz and AR.
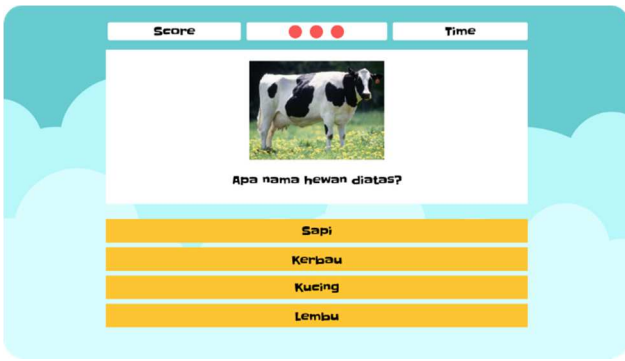
Fig. 2. Prototype of the Quiz page

Fig. 2 depicts the Quiz page, including the quiz scores, the user's mistakes, and time duration. Users will be presented with an image and text as a question, with four answer options.
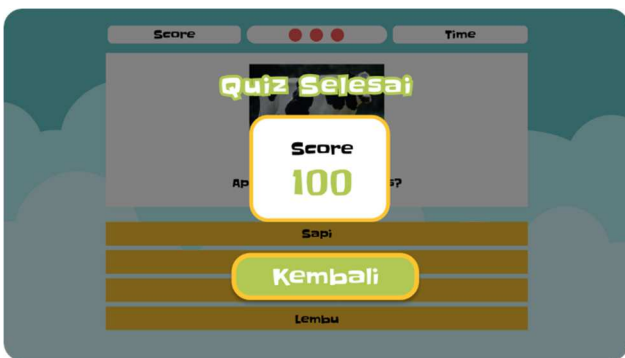

Fig. 3. Prototype of the End of the Game page

After the game, the user will see a page similar to the one shown in Fig. 3 that displays the user's quiz score.
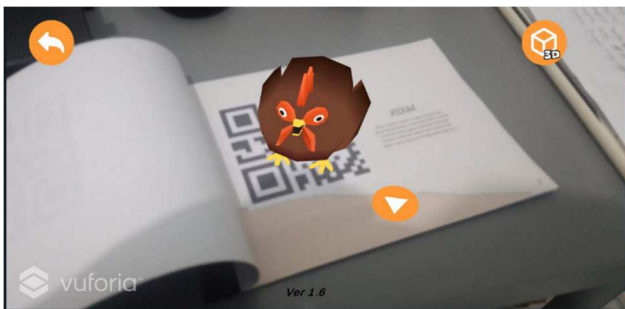

Fig. 4. Prototype of the Scanning Marker Display

Users can select the 3D assets from the Asset Menu page, and then scan them, as shown in Fig. 4, to display the 3D object.

C. Results of Data Collection Through Questionnaires

To create this questionnaire, a few key information requirements were established based on the defined target respondents. This data pertains to the respondents' understanding of Augmented Reality, their use of educational games, and their interest in incorporating AR into educational games. A total of ten questions were chosen to aid in the collection of this data.

The data for this study were collected using a Google Form that was distributed to elementary school teachers and parents or guardians of elementary students. The results from 50 respondents are as follows:

TABLE I. SCHOOLING LEVEL OF STUDENTS FROM THE RESPONDENTS

Variable	Total of students	Percentage
Grade 1 Elementary School	8	16 %
Grade 2 Elementary School	8	16 %
Grade 3 Elementary School	8	16 %
Grade 4 Elementary School	10	20 %
Grade 5 Elementary School	9	18 %
Grade 6 Elementary School	7	14 %
Not yet in school	0	0 %

According to Table I, the majority of the 50 respondents have/represented children in 4th-grade elementary school, with as many as 10 respondents (20%).

TABLE II. RESPONDENT'S KNOWLEDGE OF AUGMENTED REALITY ("DO YOU KNOW WHAT AUGMENTED REALITY IS?")

Variable	Total Respondents	Percentage
Yes	26	52 %
No	24	48 %

According to Table II, 26 of the 50 respondents are already familiar with AR.

TABLE III. RESPONDENTS' EXPERIENCE IN USING AUGMENTED REALITY APPLICATIONS. ("HAVE YOU EVER USED APPS OR GAMES THAT ARE BASED ON AUGMENTED REALITY?")

Variable	Total Respondents	Percentage
Yes	23	46 %
No	27	54 %

According to Table III, 27 respondents (54%) have never used an Augmented Reality application.

TABLE IV. RESPONDENTS' DEVICE PLATFORM. ("ON WHAT PLATFORM DID YOU USE THE AR APP?")

Variable	Total Respondents	Percentage
Android	22	44 %
iOS	6	12 %
Haven't used it	22	44 %

According to Table IV, most respondents use an Android device. However, there is a slight difference between this table and the previous table, which shows that 27 people have not used an AR application, whereas only 22 people in this table have. This could be due to 5 respondents incorrectly answering what platform they used.

TABLE V. RESPONDENT'S KNOWLEDGE OF AUGMENTED REALITY. ("PLEASE GIVE A BRIEF EXPLANATION ABOUT YOUR KNOWLEDGE OF AUGMENTED REALITY.")

Variable	Total Respondents	Percentage
Correct/ Close Enough Explanation	27	54 %
Don't know	23	46 %

According to Table V, 54 percent of the respondents have a clear knowledge of Augmented Reality and how it works.

TABLE VI. RESPONDENTS' EXPERIENCE ON USING EDUCATIONAL GAME. ("HAVE YOU EVER USED GAME MEDIA TO HELP YOUR CHILD'S EDUCATION?")

Variable	Total Respondents	Percentage
Yes	24	48 %
No	26	52 %

Table VI shows that 52 percent of the respondents have never used games as an educational medium.

TABLE VII.   RESPONDENTS' OPINION ON GOOD EDUCATIONAL GAMES. ("WHAT IS THE MOST IMPORTANT ASPECT IN A CHILDREN'S EDUCATION GAMES?")

Variable	Total Respondents	Percentage
Educational information provided	29	58 %
Thrill and fun while playing	21	42 %

Table VII shows that 58 percent of respondents believe the most important aspect of a good educational game is the "educational information provided."

TABLE VIII.   RESPONDENTS' ASSESSMENT OF EDUCATIONAL GAMES. ("DO YOU THINK EDUCATIONAL GAMES ARE HELPFUL FOR CHILDREN'S EDUCATION?")

Score	Total Respondents	Percentage
1	0	0 %
2	1	2 %
3	8	16 %
4	21	42 %
5	20	40 %

Table VIII shows that 42 percent of respondents gave a score of 4 out of 5 to the statement that "educational games are helpful for children's education".

TABLE IX.   RESPONDENTS' INTEREST IN PLAYING EDUCATIONAL GAMES. ("ARE YOU INTERESTED IN PLAYING EDUCATIONAL GAMES?")

Variable	Total Respondents	Percentage
Yes	47	94 %
No	3	6 %

According to Table IX, 94 percent of the respondents are interested in playing educational games.

TABLE X.   RESPONDENTS' INTEREST IN PLAYING AUGMENTED REALITY GAMES. ("ARE YOU INTERESTED IN PLAYING AR GAMES?")

Variable	Total Respondents	Percentage
Yes	40	80 %
No	10	20 %

According to Table X, 70% of respondents are interested in playing augmented reality games.

D. Evaluation

The author conducted usability testing on this study's chosen target user group. The questions and task scenarios were created after determining the topic and critical information that needed to be gathered.

The application's user satisfaction and ease of use have been chosen as the subject of this evaluation. The questions for these tests are shown in Tables XI and XII:

TABLE XI.   USER SCENARIO

No	User Scenario
1	Click the Input Name Button to enter your name.
2	Select the material with the title "Animal"
3	Correctly answer a question
4	Incorrectly answer a question
5	Go back to the game's main menu
6	Select the AR Object titled "Chicken"
7	Click the play button at the AR Object
8	Play the AR Animation

TABLE XII.   INTERVIEW QUESTIONS

No	Questions
1	Are you familiar with the AR concept?
2	Have you tried applications or games that use AR?
3	Do you think educational games affect the learning process?
4	Do you think the ARIPA app can help online learning?
5	Did you have any difficulty when using the app?

6	What features do you suggest should be implemented in the app?

The following are the results from the Usability Testing Interview that was conducted on eleven elementary students and two adults:

TABLE XIII.   USABILITY TESTING 1 RESULTS

No	User Story	Page	Success Indicator	Success Percentage
1	Input your name	Main Menu, Name Input	The user can input their name into the system	12/13 respondents were successful (92,31%)
2	Chose the "Animal" category	Quiz Category	The user can choose the "Animal Category"	13/13 respondents were successful (100%)
3	Correctly answer a question	Quiz	The user can answer one question correctly	13/13 respondents were successful (100%)
4	Incorrectly answer a question	Quiz	The user can answer one question incorrectly	13/13 respondents were successful (100%)
5	Go back to the main menu	Main Menu	The user can go back to the main menu after ending a quiz	13/13 respondents were successful (100%)
6	Choose the "Chicken" AR Object	AR Category	The user can choose the "Chicken" Object in the AR category	13/13 respondents were successful (100%)
7	Scan the provided marker	AR Object Display	The user can scan the AR Object marker from the marker book	13/13 respondents were successful (100%)
8	Play the AR animation	AR Object Display	The user can play the AR animation	13/13 respondents were successful (100%)

According to Table XIII, the usability testing of the app received a score of 99.04% from 13 respondents. Besides testing the task scenario, the author also queried the respondent's satisfaction after using the app, as shown in Table XIV.

TABLE XIV.   USABILITY TESTING 2 RESULTS

No	Question	Respondent's Answer
1	Is this application satisfying to play	13/13 Respondents answered: "This app is satisfying".
2	Is the quiz difficult to answer?	12/13 Respondents answered: "Quite difficult". 1/13 Respondents answered: "Easy".
3	Will you be interested if this app is used to learn in the classroom?	13/13 Respondents answered: "Interested".

E. Discussion

In this study, an original augmented reality educational game was created to increase elementary school students' motivation and learning performance. Several features were developed to increase students' interest and success in studying. The quiz feature was designed to reinforce studies through game-based learning with points, hearts, and time limits. Another feature, the 3D AR model, was created to allow students to engage and interact with the material being explained.

In the evaluation phase of the study, eleven students and two adults were interviewed and tested to assess the impact

of the ARIPA game on students' motivation and learning performance. Through usability testing, it was discovered that 99.4% of respondents completed the task scenario successfully, indicating the game's ease of use. In a separate interview, users who have used the app stated that the app is enjoyable to use and that they would like to use it in the classroom.

The evaluation's positive outcome indicated that augmented reality in education is promising and beneficial. This approach brings a new perspective to online teaching and provides students with a more enjoyable learning experience, especially during the COVID-19 pandemic.

V. CONCLUSION AND SUGGESTIONS

The educational game ARIPA was successfully constructed using Android and AR technology as a base. The Scrum methodology greatly aided this project, which organizes the game development process and task division. Students who have played the game were satisfied because it allows them to play an AR-based game while learning new materials. Not only were the students drawn to the virtual game but also to the marker-based system because it has a physical form that they can touch and play with. A few suggestions for how this research can be further developed and improved include adding more and newer varieties of 3D objects, developing a level system for the game to group users based on their education level, implementing a custom quiz and object feature for teachers, implementing different account systems for teachers and students, developing the app to be iOS compatible, and developing the game further to include higher educational material levels.

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