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Design and Preliminary Evaluation of an Android Educational Game for Respiratory-System Learning in Grade V

Meisyah Safira Putri[1]*, Herlambang Saputra[2], Ariansyah Saputra[3]
Politeknik Negeri Sriwijaya, Palembang, Indonesia
*Corresponding Author: meisyahsap@gmail.com

ABSTRACT

Elementary science instruction at SD Negeri 85 Palembang primarily used lectures, textbooks, and board-based explanations, indicating the need for a more interactive supplementary learning medium. This study aimed to develop an Android educational game, Oxygen: Petualangan Oksigen, for Grade V learning about respiratory systems in plants, animals, and humans, and to evaluate its functional performance, media validity, and student responses. The study employed a research-and-development method using a modified Game Development Life Cycle consisting of initiation, pre-production, production, testing, and release. Developed with Unity, the game integrates learning materials, platformer gameplay, multiple-choice questions, and drag-and-drop activities. Evaluation included Black Box Testing, media validation by six experts, and classroom administration involving 119 of 129 Grade V students, representing a participation rate of 92.25%. Two separate five-item questionnaires were used to identify students' initial learning needs and gather their responses after using the game. Black Box Testing showed that all documented application functions operated as intended. Media-expert assessments produced scores of 95.00%, 88.33%, 93.33%, 90.00%, 86.67%, and 93.33%, with an aggregate score of 328 out of 360 (91.11%), categorized as Very Valid for presentation, navigation, and graphical design. The comparatively lower ratings concerned character and asset design (79.17%) and quiz presentation (83.33%). Students also provided favorable immediate responses regarding the game's appearance, ease of use, and attractiveness. However, the initial and post-use questionnaires measured different constructs and therefore cannot demonstrate improved understanding or learning effectiveness. Moreover, content accuracy and instructional quality were not separately validated. Thus, Oxygen: Petualangan Oksigen is functionally operational and considered highly valid in terms of media presentation. These findings support its use as a supplementary classroom prototype. Further studies should involve content and pedagogical experts, equivalent pretest–posttest achievement measures, and a comparison group to determine its educational effectiveness.

Keywords: *Android educational game, elementary science, Game Development Life Cycle, respiratory system, System Usability Scale*

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INTRODUCTION

Respiratory-system learning in Grade V requires students to understand how living organisms obtain and exchange gases through different organs and processes. Based on classroom observation and interviews with Grade V IPAS teachers at SD Negeri 85 Palembang, learning activities were still dominated by lectures, textbooks, and board-based explanations. The limited variation of learning media made the topic less interactive and created a need for a supplementary medium that could present the material through visual, interactive, and game-based activities.

Digital game-based learning combines the motivational features of games, such as goals, feedback, and progression, with instructional content, on the premise that engagement can support sustained practice. Mayer's cognitive theory of multimedia learning explains how combining words, static or animated images, and interactivity can support meaningful learning when the design manages the learner's limited working-memory capacity; the same body of theory also cautions that decorative animation, sound, and game mechanics unrelated to the learning content can impose extraneous cognitive load and crowd out germane processing of the material [1], [2]. Retrieval-practice

research indicates that answering questions about material, rather than simply re-reading it, produces more durable learning, which is directly relevant to the multiple-choice and drag-and-drop quiz components of the game evaluated here. This literature is used in the Discussion to interpret which mechanics plausibly support learning and which may mainly add entertainment value.

Elementary and secondary students commonly conflate breathing with the broader biological process of respiration, and a well-documented misconception holds that only animals respire while plants only photosynthesize, or that plants perform a kind of reverse breathing, taking in carbon dioxide and releasing oxygen only, rather than carrying out both photosynthesis and respiration [3], [4]. Addressing this specific misconception is directly relevant to a game that separately covers plant, animal, and human respiration, and the game-design description in the Methodology section states how each module attempts to address it; whether the attempt succeeds is a content-validity question that has not yet been tested [5].

The game is intended to support the Indonesian Kurikulum Merdeka learning outcome (*Capaian Pembelajaran*) for IPAS, Phase C (Grades V-VI), under the IPAS Understanding element, which states that students simulate, using simple pictures, diagrams, tools, or media, the human body's organ systems, including the respiratory, digestive, and circulatory systems, and relate them to how to correctly maintain the health of those organs. The game addresses the respiratory component of this outcome for plants, animals, and humans; the specific knowledge and skills it targets are identifying the respiratory organs of each group, describing the general gas-exchange process, and recognizing at least one common misconception for each group, which should be stated explicitly as learning objectives in the curriculum-alignment matrix in the Methodology section.

Several prior studies have developed Android-based media specifically for respiratory-system content. Pahlifi and Fatharani (2019) developed Android-based learning media on the human respiratory system for senior-high biology students and evaluated it through material- and media-expert review together with a limited student trial, without a controlled learning-outcome comparison. [4], [6], [7] developed Android-based augmented-reality media on the human respiratory system for Grade V students at SDIT Sultan Agung 05 using the Borg and Gall research-and-development model, and, importantly, evaluated learning outcomes with an equivalent pretest-posttest instrument and reported a normalized gain (N-gain) of 0.73, classified as high, alongside positive teacher and student responses averaging 88%. [8], [9] developed an augmented-reality respiratory-system learning application for biology instruction and likewise combined expert review with a classroom trial. Relative to this body of work, the present study's specific contribution is the combination of platformer gameplay with content pages and two quiz formats in a single Android application organized around three organism groups (plants, animals, humans) for the elementary Grade V level; unlike [10], [11], the present evaluation does not yet include an equivalent pre/post achievement instrument or an N-gain analysis, which is identified in the Discussion and Conclusion as the most direct next step to make the evaluation comparable to that stronger precedent.

Three mechanics are combined in the game: content pages, platformer gameplay, and quizzes (multiple-choice and drag-and-drop). Content pages are intended to provide the initial verbal and pictorial explanation consistent with multimedia-learning principles. Platformer gameplay is intended to require players to act on in-game representations tied to respiratory structures or processes so that the mechanic is coupled to the content rather than merely surrounding it [12], [13], [14]; the specific coupling used in each level should be documented in the game design document described in the Methodology. The multiple-choice and drag-and-drop quizzes are intended to function as retrieval practice and as a labeling or classification task, respectively, both of which target recall and application of respiratory-system vocabulary and structure-function relationships. Whether players actually engage with the content in this coupled way, rather than treating the platforming as separate from the science, is an empirical question that internal Black Box Testing and media-expert review do not answer and that future child-user testing should address directly [15].

To respond to this need, the study developed an Android educational game entitled Oxygen: Petualangan Oksigen. The game integrates respiratory-system material for plants, animals, and humans with platformer gameplay, conventional multiple-choice quizzes, and drag-and-drop quizzes. The development process used the Game Development Life Cycle (GDLC) so that concept initiation, design, production, testing, and release could be carried out systematically [16], [17]. Developing another Android educational game is, on its own, product novelty rather than a scientific contribution; the contribution this study offers is a documented modified GDLC workflow, an explicit mapping between game mechanics and respiratory-system content for three organism groups at the elementary level, and a transparent account of what internal testing, media-expert judgment, and a single-school classroom trial can and cannot establish about classroom readiness, including a corrected treatment of the classroom questionnaire data. The study addresses five separate research questions: (1) does the application function as intended (functionality); (2) how do media experts rate its presentation, navigation, and graphical design (media feasibility); (3) how do students describe their prior attitude toward the topic and, separately, their immediate response after using the game (student response); (4) to what extent

can the classroom instruments used here support a usability judgment such as the System Usability Scale (usability); and (5) does the game improve respiratory-system understanding (learning outcome). This study reports evidence for questions 1 through 3, offers a corrected, limited answer for question 4, and explicitly does not answer question 5 with the present instruments.

MATERIAL AND METHOD

This research used a research-and-development approach. The research site was SD Negeri 85 Palembang, with a Grade V population of 129 students from classes 5A-5E. A total of 119 students who were present participated in the classroom evaluation. Data were collected through observation, teacher interviews, Black Box Testing, pre-test and post-test questionnaires, and a media-expert validation questionnaire completed by six validators [18].

The design and development process of the educational game used the Game Development Life Cycle (GDLC) method, while the analysis of data from respondents who used the educational game employed calculations based on the System Usability Scale (SUS) [19].

Game Development Method

The educational game was developed using a modified Game Development Life Cycle (GDLC). The method was adjusted to the needs of the study and consisted of five stages: initiation, pre-production, production, testing, and release [20], [21].

1. Initiation. This stage established the concept and basic requirements of the educational game. The researcher determined and studied the game genres and interactions to be used, including platformer gameplay, standard multiple-choice quizzes, and drag-and-drop quizzes, and aligned them with Grade V respiratory-system material. The initiation stage formed the foundation of the development process so that the game could be developed in a structured manner and remain aligned with the expected learning objectives [22].

2. Pre-production. This stage translated the initial concept into a more detailed design. The game mechanism was visualized and documented through a flowchart, application wireframes, and a game design document. The purpose of this stage was to ensure that the game flow, interface, content structure, and interaction sequence were clearly defined before production began [23].

3. Production. The concepts and designs from pre-production were implemented in the Android game. Production included creating the required assets and writing the program code in Unity [24], [25], [26]. The process also integrated the visual design, game flow, sound, learning content, gameplay mechanics, and programming according to the approved design.

4. Testing. Internal testing was conducted to examine the usability and functionality of the educational game and to verify that the product operated according to its development objectives. Black Box Testing was used to check buttons, page navigation, menu transitions, gameplay mechanisms, quizzes, and result displays without examining the internal program code [27].

5. Release. After testing and revision, the educational game was released in Android Package Kit (.apk) format for Grade V students at SD Negeri 85 Palembang. The APK format was selected so that the application could be distributed and installed easily on Android devices [28].

System Usability Scale (SUS) Data Analysis

The study used System Usability Scale (SUS) scoring procedures to process questionnaire data obtained from respondents. The average SUS score was calculated using the following equation [29], [30]:

$$\bar{x} = \frac{\sum x}{n} \quad (1)$$

where $\bar{x}$ is the average score, Σx is the total SUS score, and n is the number of respondents. The interpretation categories used in the study are presented in Table 1.

Table 1. Interpretation of SUS Scores

Score Range	Category	Grade	Description
0-50	Very Poor	F	Not feasible to use
51-60	Poor	D	Requires major improvement
61-70	Fair	C	Usable, but still lacking
71-80	Good	B	Feasible and sufficiently comfortable
81-100	Very Good	A	Very good and user-friendly

For each respondent, odd-numbered items (1, 3, 5, 7, and 9) were scored by subtracting 1 from the response value, while even-numbered items (2, 4, 6, 8, and 10) were scored by subtracting the response value from 5. The resulting item scores were summed and multiplied by 2.5 to obtain a SUS score [31], [32]. The average score was then obtained by summing the scores of all respondents and dividing by the number of respondents.

Pre-test and Post-test

Evaluation was carried out using pre-test and post-test questionnaires to identify changes in students' responses and perceived understanding of respiratory-system material after using Oxygen as a learning medium. The pre-test was administered before students used the game, while the post-test was administered after the learning activity using the game. The questionnaires used a 1-5 scale: 1 = Strongly Disagree, 2 = Disagree, 3 = Fairly Agree, 4 = Agree, and 5 = Strongly Agree [33], [34].

The pre-test questions were:

- Is the respiratory-system material of living organisms difficult to understand?
- Does learning only from books feel boring?
- Can learning through games make the learning process more interesting?
- Is the teacher's explanation of the material sometimes difficult to understand?
- Do you agree that respiratory-system material should be presented as a learning game?

The post-test questions were:

- Is the appearance of the Oxygen educational game attractive?
- Is the Oxygen educational game easy to use?
- Is the material presented in the Oxygen educational game easy to understand?
- Are you interested in learning using the Oxygen educational game?
- Does the Oxygen educational game help you understand the respiratory system of living organisms?

Media Expert Validation

Media-expert validation was used to evaluate the visual presentation, presentation feasibility, navigation, and graphical quality of the educational game. The validation questionnaire used a four-point Likert scale, as shown in Table 2.

Table 2. Likert Scale for Media Expert Validation

Score	***Category***
4	*Very Feasible*
3	*Feasible*
2	*Not Feasible*
1	*Very Not Feasible*

The percentage of expert validation was calculated as:

$$\text{Vah} = \frac{\text{TS}_\text{e}}{\text{TS}_\text{h}} \times 100\% \quad (2)$$

where Vah is expert validation, TSe is the total validation score obtained, and TSh is the maximum ideal score [35], [36]. The percentage was interpreted using the criteria shown in Table 3.

Table 3. Media Expert Validation Criteria

Percentage	**Validity Level**
1.00%-50.00%	Not valid / not permitted for use
50.01%-70.00%	Less valid / major revision recommended
70.01%-85.00%	Sufficiently valid / usable with minor revision
85.01%-100.00%	Very valid / usable without revision

The media validation instrument consisted of 15 items covering presentation technique, presentation feasibility, and graphical feasibility. Each item was rated using four response indicators: 1 = Strongly Disagree, 2 = Disagree, 3 = Agree, and 4 = Strongly Agree. The instrument items are presented in Table 4.

Table 4. Media Expert Validation Questionnaire

No.	Question	1	2	3	4
P1	The educational game has a structured presentation system.				
P2	The presentation flow is easy to understand.				
P3	The initial menu is presented appropriately.				
P4	The main menu is presented appropriately.				
P5	The learning-material menu is presented appropriately.				
P6	The gameplay section is presented appropriately.				
P7	The quiz section is presented appropriately.				
P8	The design makes it easy for users to perform the initial action.				
P9	The main-menu design is consistent with the overall interface.				
P10	The material-menu display is easy to understand and access.				
P11	The gameplay navigation is easy to understand.				
P12	The quiz-menu design supports the learning objectives.				
P13	The character design and overall assets are appropriate.				
P14	The use of color and typography in the educational game is appropriate.				
P15	The overall layout is balanced and harmonious.				

RESULTS AND DISCUSSION

Game Interface Display

The GDLC process produced the Android educational game Oxygen: Petualangan Oksigen. The following displays were included in the revision because they represent the main entry points and navigation structure of the developed game.

Figure 1. Initial Page of Oxygen: Petualangan Oksigen

The initial page is the first screen displayed when the educational game starts. It contains a Start button that directs the user to the main menu. Additional navigation icons are located at the top of the screen for viewing the developer profile, exiting the application, turning sound effects on or off, and opening the game instructions. This page provides the first visual impression of the educational game and functions as the entry point before users access the main learning content.

Figure 2. Developer Information Page

The developer information page displays the identity of the educational-game developer, including the developer's name, institution, study program, and related information. The page is equipped with a close/back navigation button so that users can return to the previous or main menu without closing the application.

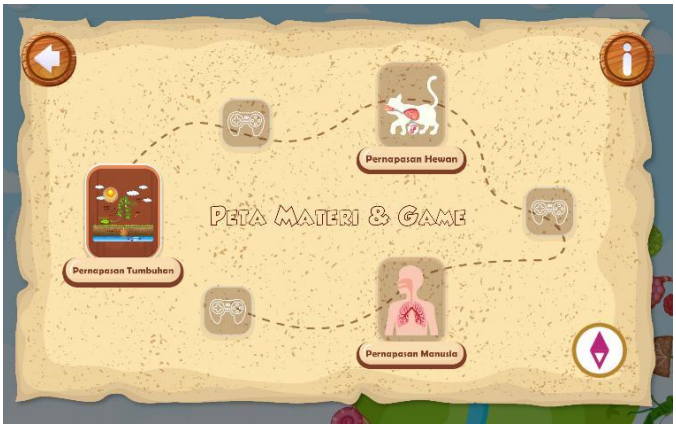

Figure 3. Main Menu / Material and Game Map

The main menu appears after the user selects the Start button on the initial page. This screen presents six principal access points: plant respiratory-system material, plant gameplay, animal respiratory-system material, animal gameplay, human respiratory-system material, and human gameplay. Each button directs the user to the corresponding feature and creates a structured pathway between learning materials and game activities.

Black Box Testing Result

Black Box Testing was carried out internally during the testing stage. The test focused on whether the application functions operated according to their intended behavior. The tested functions included navigation buttons, page transitions, gameplay mechanisms, quiz processes, and result displays. All tested functions operated as expected, indicating that the game was functionally ready for classroom use in the tested scenarios.

Pre-test and Post-test Results

The classroom evaluation involved 119 students who were present from the total Grade V population of 129 students. The results in Table 5 show that the mean post-test score was higher than the mean pre-test score in all five classes. The combined values were classified as Good using the study's interpretation.

Table 5. Pre-test and Post-test Results with SUS-Based Scoring

Class	Students	Present	Pre-test Mean	Post-test Mean	Combined Mean	Category
5A	27	25	76.0	80.0	78	Good
5B	24	24	75.8	78.3	77	Good
5C	26	25	70.4	73.6	72	Good
5D	26	21	71.4	74.3	73	Good

Class	Students	Present	Pre-test Mean	Post-test Mean	Combined Mean	Category
5E	26	24	75.8	78.3	77	Good

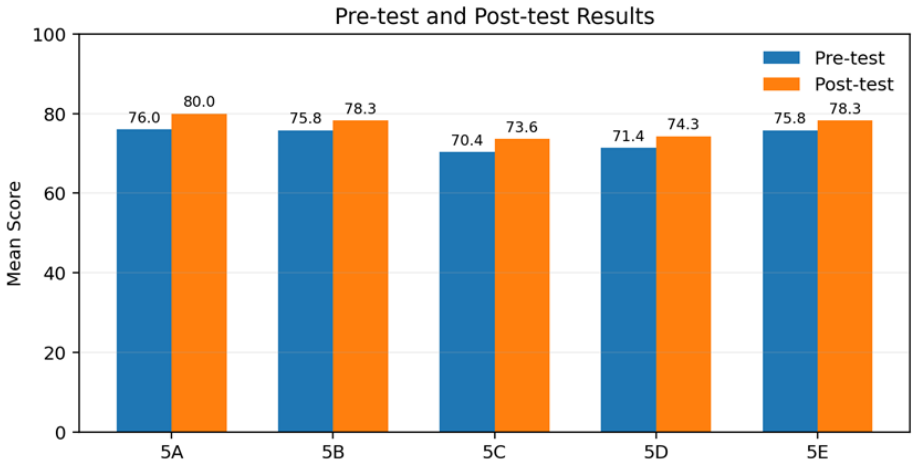

Figure 4. Comparison of Pre-test and Post-test Mean Scores

Class 5A increased from 76.0 to 80.0; class 5B from 75.8 to 78.3; class 5C from 70.4 to 73.6; class 5D from 71.4 to 74.3; and class 5E from 75.8 to 78.3. The consistent upward pattern indicates a more positive response after students used the Oxygen educational game.

Media Expert Validation Results

The media-expert validation questionnaire was distributed to six media experts through Google Forms. The Google Form was accompanied by a Google Drive link containing the educational game in APK format so that the validators could access and assess the application. The item-level results are presented in Table 6.

Table 6. Media Expert Validation Results

No.	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5	Expert 6
P1	4	4	3	4	3	4
P2	4	4	4	4	3	3
P3	4	3	4	4	4	4
P4	3	3	4	4	4	4
P5	4	4	3	3	4	4
P6	4	3	4	4	4	3
P7	3	3	4	4	3	3
P8	4	4	4	4	3	3
P9	4	4	4	4	4	4
P10	4	4	4	4	3	4
P11	4	4	4	3	2	4
P12	4	3	4	3	4	4
P13	3	3	3	3	3	4
P14	4	3	3	3	4	4
P15	4	4	4	3	4	4
Total Score (TSe)	57	53	56	54	52	56
Maximum Score (TSh)	60	60	60	60	60	60
Validation Result	95%	88%	93%	90%	86%	93%

No.	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5	Expert 6
Criteria	Very Valid	Very Valid	Very Valid	Very Valid	Very Valid	Very Valid

The total validation scores were 57, 53, 56, 54, 52, and 56 out of a maximum ideal score of 60 for each validator. The corresponding percentages reported in the revision document were 95%, 88%, 93%, 90%, 86%, and 93%. All six results fall within the 85.01%-100.00% interval and were therefore classified as Very Valid. These results indicate that the game met the study's media-feasibility criteria in terms of presentation technique, presentation feasibility, and graphical feasibility.

DISCUSSION

The combined evaluation shows that Oxygen: Petualangan Oksigen fulfilled three practical requirements for classroom implementation. First, Black Box Testing confirmed that the tested game functions operated correctly [27]. Second, all six media experts placed the product in the Very Valid category, indicating that its presentation, navigation, and graphical design were considered appropriate. Third, the post-test mean exceeded the pre-test mean in every participating class, while the combined class scores remained in the good category [37], [38].

The interface structure also supports the intended learning sequence. Students enter through a simple initial page, can access instructions and developer information, and then move to a material-and-game map that separates the respiratory topics of plants, animals, and humans. The integration of material pages, platformer gameplay, multiple-choice questions, and drag-and-drop activities provides varied forms of interaction within one Android application. Based on the data provided in this study, the game can be considered a feasible supplementary medium for Grade V respiratory-system learning at SD Negeri 85 Palembang.

[23], [24] developed Android-based respiratory-system learning media for senior-high biology students and relied on material- and media-expert review with a limited student trial, similar in evidentiary strength to the media-expert component of this study. [31]combined augmented reality with respiratory-system biology content and likewise combined expert review with a classroom trial. [3], working with the same Grade V respiratory-system topic at a different Indonesian elementary school, used an equivalent pretest-posttest achievement instrument and reported a high normalized gain (N-gain = 0.73) alongside positive teacher and student responses averaging 88%; this is a materially stronger design than the present study's non-equivalent questionnaires, because it measures the same construct at two time points and can therefore support a claim about learning outcomes. The most direct improvement available to this line of work, illustrated by that comparison, is to replace the current pre-use and post-use questionnaires with a single, curriculum-aligned achievement instrument administered before and after use, ideally with N-gain or an equivalent effect-size calculation and, where feasible, a comparison class.

CONCLUSION

This study developed Oxygen: Petualangan Oksigen, an Android educational game prototype for Grade V respiratory-system learning, using a modified Game Development Life Cycle consisting of initiation, pre-production, production, testing, and release. The game was built in Unity and combines respiratory-system content for plants, animals, and humans with platformer gameplay, multiple-choice quizzes, and drag-and-drop quizzes. Within the scenarios and devices actually tested, Black Box Testing found that the documented application functions operated as expected. Six media experts rated the product's presentation, navigation, and graphical design favorably, with corrected percentages of 95.00%, 88.33%, 93.33%, 90.00%, 86.67%, and 93.33% (aggregate 91.11%), all within the study's Very Valid band for media presentation specifically, alongside item-level weaknesses in character and asset design (P13, 79.17%) and quiz-section presentation (P7, 83.33%) that should be addressed in revision.

In the classroom evaluation, 119 of 129 enrolled students (92.25%) completed a pre-use needs and attitude questionnaire and a separate post-use response questionnaire. Because these are non-equivalent, different-construct instruments, this study does not report a valid combined or pre/post score, does not classify the results using System Usability Scale categories, and does not claim that the post-use responses demonstrate improved respiratory-system understanding or educational effectiveness. The evidence instead supports a narrower, evidence-bounded conclusion: the prototype is functionally operational in the tested scenarios, it is rated favorably by media experts on presentation criteria, and it received a generally favorable immediate response from students on the specific items asked. Content accuracy, curriculum alignment, and instructional quality have not yet been validated by a content or pedagogy expert, and classroom usefulness for actual learning remains preliminary and untested.

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