

Design and Analysis of UI Effectiveness for SDGs Interactive Learning Media Using Heuristic Evaluation

Deli Deli^{1*}, Suwarno Suwarno², Joantika Lewis³, Risna Yunita⁴

Abstract—Interactive learning media must be capable of presenting the concept of Sustainable Development Goals (SDGs) in an engaging and easily understandable way for students in support of achieving the Sustainable Development Goals. However, the effectiveness of such media is strongly influenced by user interface (UI) quality, as poor UI design can cause confusion, reduce user engagement, and hinder users' understanding of SDG concepts. This research aims to develop and analyze interactive learning media that support the dissemination of SDG content. The Multimedia Development Life Cycle (MDLC) method was used to develop the interactive learning medium, and the user interface was analyzed using the heuristic evaluation method, with questionnaires distributed to 200 high school students. The results show that the developed interactive learning medium achieved a "High" level of UI effectiveness with an average score of 4.04. The aesthetic and minimalist design principle (HE08) was the indicator that scored highest, indicating that respondents considered the system's visual design well implemented, ensuring users felt comfortable and did not encounter significant usability issues. The principles of error prevention (HE05) and helping users recognize, diagnose, and recover from errors (HE09) received lower scores, highlighting areas that require improvement. Overall, studies have demonstrated that the interactive learning medium improves student engagement and the learning experience with respect to SDG concepts. This research contributes to the development of interactive learning media and guides future research on interface improvement.

Index Terms—Heuristic evaluation, interactive learning media, multimedia development life cycle, sustainable development goals, UI effectiveness.

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I. INTRODUCTION

In this era of globalization, sustainable development has become an increasingly crucial issue, given its significant impact on social, economic, and environmental welfare. The Sustainable Development Goals (SDGs) are development plans that aim to achieve sustainable development, prioritizing human rights and equality across social, economic, and environmental domains [1]. The SDGs were established to address national issues arising from various inequalities within countries, particularly in education [2]. The SDGs represent an important agenda that many countries have adopted to advance global human welfare. The SDGs agenda has 17 goals that were formulated in July 2014 [3], including: (i) No poverty; (ii) Zero hunger; (iii) Good health and well-being; (iv) Quality education; (v) Gender equality; (vi) Clean water and sanitation; (vii) Affordable and clean energy; (viii) Decent work and economic growth; (ix) Industry, innovation, and infrastructure; (x) Reduced inequalities; (xi) Sustainable cities and communities; (xii) Responsible consumption and production; (xiii) Climate action; (xiv) Life below water; (xv) Life on land; (xvi) Peace, justice, and strong institutions; and (xvii) Partnerships for the goals [4]. Multilevel collaboration is required to achieve these goals, although implementation continues to face financial and resource constraints [5], [6]. Education is one of the most effective approaches to achieving the SDGs. Education for sustainable development (ESD) is a key driver in instilling values and skills relevant to sustainability issues [7]. ESD aims to increase students' awareness and active participation in sustainable development efforts [8]. However, ESD-based learning tools remain limited [9], so more interactive, easy-to-understand learning media are needed.

Current developments in digital technology open great opportunities to support learning, including in the context of the SDGs. Technology has been applied in everyday life, particularly in education, making work and learning more effective and efficient [10]. Experts in educational technology have long recognized the great potential of computer technology to transform teaching and learning. Academic journals specializing in educational technology often publish

studies on how technologies such as computers and the internet can accelerate learning, expand and democratize access to education, and encourage interactivity, engagement, and collaboration [11]. One important element of the learning process that must keep pace with technological developments is learning media [12]. A medium is a means of delivering messages from the sender to the recipient [13]. Digital learning media, better known as e-learning, is a technology-based method of delivering teaching materials that functions as a medium for teaching, training, and learning wherever and whenever needed [14].

In the context of the SDGs, interactive digital learning media can support understanding of sustainability concepts and increase student motivation to learn. Interactive learning media refers to any digital tools or resources that require learners' active participation and engagement in the learning process. Such media can come in the form of animations, simulations, games, and other multimedia elements, creating a more dynamic and engaging learning experience [15]. This approach enables an engaging learning process and creates new opportunities to teach students about sustainability, with special emphasis on global issues. Interactive learning media can effectively strengthen students' understanding of the SDGs, as this approach increases student participation and enables learning to take place anytime, anywhere.

However, the UI quality plays a major role in determining how effective interactive learning media can be. The user interface can hinder understanding and reduce student engagement if it is too complex and poorly designed. The Heuristic Evaluation method can be used to evaluate the quality of the user interface, as it is a frequently used, simple, and efficient method for UI evaluation [16]. UI evaluation for SDGs interactive learning media has not been prioritized, as previous research has primarily focused on content development. Based on this, this study has two main objectives: (1) to develop an interactive learning medium on SDGs content, and (2) to analyze the effectiveness of the user interface (UI) using heuristic evaluation to assess usability, identify interaction obstacles, and provide design recommendations. The combination of the interactive learning media development process and usability analysis within a single comprehensive framework makes this study significant. This study contributes to the availability of interactive learning media that support ESD, provides guidance to developers on heuristic-based UI evaluation, and strengthens the literature on UI quality in digital learning for the SDGs.

II. RELATED WORK

In improving students' comprehension of the SDGs, research on interactive learning media for sustainability education has shown promising results. Reference [17] found that integrating real-world simulations with game-based learning (GBL) effectively enhances engagement and broadens understanding of sustainability issues. The use of interactive digital tools to make difficult SDGs topics easier to understand was highlighted in their findings. Similarly, [18] found that

interactive applications such as Nearpod and Edpuzzle significantly increase students' awareness of environmental issues and promote sustainable behaviors, suggesting that these platforms can support learning outcomes related to the SDGs. Together, these studies indicate that interactive and game-based learning media are particularly important for SDGs education, as the complexity and interdisciplinary nature of SDGs concepts are difficult to convey effectively through conventional, non-interactive learning methods.

Animation as an educational aid was also highlighted in studies on media development. Reference [19] developed an animated interactive learning module using the Multimedia Development Life Cycle (MDLC) and found it effective in enhancing student motivation. This finding aligns with [20], which found that animated educational videos improve high school students' comprehension and yield notable learning gains. These results consistently indicate that animation-based media can help make complex subjects more understandable, increase motivation, and create meaningful learning experiences. These findings demonstrate the feasibility of using animation-based development methods, such as MDLC, to produce effective and engaging interactive learning media.

Furthermore, the quality of UI directly impacts the design of interactive multimedia. Reference [14] emphasized that consistent, user-friendly UI elements improve overall learning experiences and increase learners' comfort with game-based educational media. Despite these findings, most research focuses more on media and content development than on systematically evaluating user interface quality. This phenomenon indicates a research gap: UI quality is often assumed rather than empirically assessed using standardized usability frameworks.

Taken together, these studies offer substantial evidence supporting the effectiveness of interactive and animation-based media in education. Nevertheless, there is a lack of research integrating the development of SDG-focused interactive media with a structured evaluation of the user interface using methods such as heuristic evaluation. To address this gap and provide a more comprehensive understanding of usability in interactive SDGs learning media, this study combines heuristic-based UI analysis with the development of interactive learning media.

III. RESEARCH METHOD

A. Research Flow

This research begins by identifying the problem of the lack of effective interactive learning media for SDGs content. Next, a literature review was conducted to gather theories, prior research, and concepts in UI/UX and heuristic evaluation that would serve as the basis for developing interactive learning media. After that, the research entered the interactive media development stage using the MDLC approach to develop a structured interactive learning medium ready for evaluation. Following the development of the interactive learning media, a research design comprising variables, indicators, and usability assessment instruments was created. The next stage involved data collection through preliminary observation and a

heuristic-based questionnaire distributed to students as end users. The data were analyzed using a series of statistical tests, including validity and reliability tests, descriptive analyses, and evaluation of each heuristic evaluation indicator to assess the effectiveness of the UI. The study concluded with a summary of the findings on the effectiveness of interactive learning media and interface quality, and recommendations for future development.

B. Development Stage

This study uses a mixed-method approach, combining an applied approach and a quantitative approach. The authors utilize the MDLC method to develop interactive learning media through an applied approach. The MDLC is a structured approach to the design, development, and implementation of multimedia systems [21]. This method was chosen because it is well-suited for developing interactive and effective multimedia applications. MDLC involves six phases: concept, design, material collection, assembly, testing, and distribution. The MDLC phase diagram is illustrated in Fig. 1.

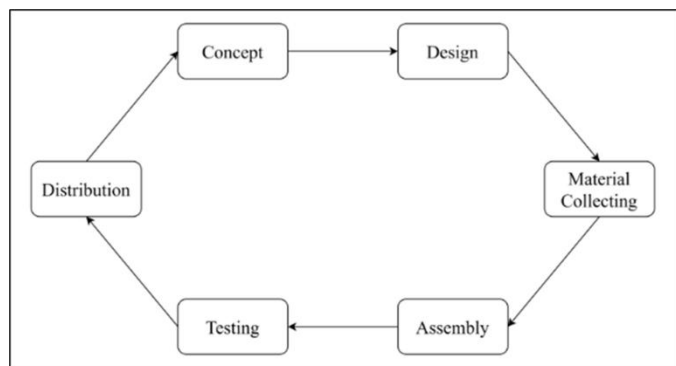


Fig. 1. MDLC diagram.

The following describes each phase in the implementation of the interactive learning medium using MDLC:

1) Concept

In this phase, the basic concept for the interactive learning medium to be developed was established. The interactive learning medium aims to support the dissemination of the SDGs, enabling users to understand them more effectively. The concept incorporates features that enhance the learning experience, including informative material, multimedia elements, and interactive activities such as quizzes designed to test users' comprehension, making the learning experience not only passive but also encouraging active participation.

2) Design

The next phase involves designing the navigation flow, user interface, and content for the interactive learning medium. Figma was used to develop a prototype that includes the menu structure, page layout, and visual design of the application elements. Table 1 presents a storyboard developed by the authors to illustrate the details of each scene in the interactive

learning medium.

Table 1.
Interactive Learning Media Storyboard

Page/Scene	Design	Description
Loading Screen Page		Initial screen displaying the application logo and loading animation before entering the Main Page.
Main Page		Shows the "Start" button as the gateway to the main menu.
Menu Page		Provides navigation options: About SDGs, 17 SDGs Goals, and Quiz.
About SDGs Page		Presents an overview of SDGs with Next/Prev navigation.
17 SDGs Goals Page		Displays 17 goal icons; each icon leads to a detailed explanation.
Goal Detail Page		Shows detailed information of a selected SDG goal with navigation between goals.
Quiz Introduction Page		Contains brief instructions and a "Start Quiz" button.
Quiz Page		Multiple-choice questions on SDGs with automatic Next/Submits flow.
Quiz Result Page		Displays the final score and summary of correct/incorrect answers.
Help/Documentation Panel		A help panel accessible from all pages, providing usage instructions.

3) Material collecting

During this phase, the authors collect the materials to be used in the application. Figure 2 shows the materials collected for developing the interactive learning medium.

4) Assembly

After the materials are collected, the authors integrate all the collected multimedia elements and code them into an application in Adobe Animate.



Fig. 2. Material collecting.

5) *Testing*

In this phase, the developed interactive learning medium is tested using black-box testing. The authors carry out this testing to ensure that all functions work correctly according to the design. The black-box testing technique focuses on functional testing, in which the testing process is carried out based on inputs and outputs without examining the program code. Each feature is tested to ensure that its function aligns with the expected results. Table 2 presents the results of black-box testing.

Table 2. Black-Box Testing Result

Test Item	Test Scenario	Expected Result	Status
Loading Screen and Main Page	Press the "Start" button and toggle Audio ON/OFF	Navigates to the Menu; background music activates/deactivates correctly	Pass
Menu Page	Press each menu option (About SDGs, SDGs Goals, Quiz)	Each menu opens according to its intended function	Pass
About SDGs Page	Display the SDGs explanation	Information appears correctly and is readable	Pass
17 SDGs Goals Page	Press each SDG goal icon	A detailed page for each selected goal is displayed	Pass
Goal Detail Page	Press buttons (Introduction, Impact, Efforts, Goal List, Previous, Next)	All navigation buttons function properly	Pass
Quiz Introduction Page	Display quiz instructions and press "Start Quiz."	Instructions are shown clearly; the Start Quiz button works correctly	Pass
Quiz Page	Answer all questions and view automatic feedback	Correct/wrong feedback displays properly; questions appear as intended	Pass
Quiz Result Page	Display final score and answer summary	Final score and correct/incorrect information appear correctly	Pass
Help / Documentation Panel	Open the help/documentation panel	Instructions appear, and the panel can be closed properly	Pass

6) *Distribution*

After the application is declared ready for use during testing, the distribution phase is carried out. In this research, the application is distributed as an APK file via a Google Drive link and can be installed on Android devices. This distribution stage allows users to use the application in accordance with its development objectives.

C. *Heuristic Evaluation Method*

Heuristic evaluation is a simple yet efficient method for assessing the quality of user interface design [16]. In this method, a group of evaluators reviews an interface using a set of heuristic design principles or guidelines to identify usability issues. Based on these findings, the evaluators provide appropriate improvement suggestions. This approach helps detect usability issues that may go unnoticed by the average user, allowing for more targeted improvements [22], [23]. In this study, the interface evaluation was conducted using the heuristic evaluation framework proposed by Jakob Nielsen, comprising 10 main principles. These principles were used as the basis for evaluating the user interface of the interactive learning medium. The ten heuristic principles are as follows:

- 1) Visibility of system status: the system should always inform users about what is happening within a reasonable time.
- 2) Match between system and the real world: the interface should use language, terms, and concepts familiar to the user, rather than system jargon.
- 3) User control and freedom: users should be able to easily undo or redo actions and navigate the system without feeling restricted.
- 4) Consistency and standards: the design should maintain consistency in interaction patterns throughout the system.
- 5) Error prevention: the design should minimize the possibility of user errors through careful design and confirmation mechanisms.
- 6) Recognition rather than recall: the design should reduce users' memory load by making options, actions, and information visible.
- 7) Flexibility and efficiency of use: the system should support both novice and experienced users by providing efficient interaction mechanisms.
- 8) Aesthetic and minimalist design: the interface should maintain a clean design that avoids unnecessary or irrelevant information.
- 9) Help users recognize, diagnose, and recover from errors: error messages should be clear and provide guidance for recovery.
- 10) Help and documentation: the system should provide accessible guidance or documentation to assist users when needed.

Each of these heuristic principles was then adapted into a questionnaire item for data collection, as detailed in the operational definitions of variables below.

D. *Data Collection Method*

The study conducted preliminary observations on students' use of interactive learning media. These observations provided an initial overview of ease of use, interface design, and the difficulties students encountered during the learning process. Data collection was conducted using a questionnaire to obtain quantitative measures of user satisfaction and experience.

The measurement and evaluation criteria in this study were determined using a Likert scale, a commonly used instrument for assessing people's attitudes, opinions, and perceptions of a

given phenomenon. The Likert scale in this study used five options: "Strongly Disagree," "Disagree," "Neutral," "Agree," and "Strongly Agree." In addition, the questionnaire items were developed using Nielsen's 10 heuristics. Each item represents a single heuristic, yielding a total of 10 questions.

E. Data Analysis Method

The data collected through the distribution of questionnaires were quantitatively analyzed using the Statistical Package for the Social Sciences (SPSS) version 30 software. This analysis was conducted to understand better the relationships among the variables studied in this research.

F. Variables and Indicators

This research has two main variables:

1) Independent variable (X)

The independent variable in this research is heuristic evaluation (X), which is a user interface evaluation method used to assess the extent to which the learning medium meets usability principles. According to Nielsen, heuristic evaluation consists of ten main principles, including visibility of system status, match between system and the real world, user control and freedom, consistency and standards, error prevention, recognition rather than recall, flexibility and efficiency of use, aesthetic and minimalist design, help users recognize/diagnose/recover from errors, and help and documentation. These variables are measured through user assessments of system clarity, language suitability, design consistency, error prevention, and the availability of help or guidance in the interactive learning medium.

2) Dependent variable (Y)

The dependent variable (Y) in this research is the effectiveness of the learning medium, which reflects the extent to which the interactive medium improves students' comprehension of the material, boosts their motivation to learn, and provides an engaging, interactive learning experience. The effectiveness of the interactive learning medium is measured by students' perceptions of ease of use, clarity of display, visual appeal, and the medium's utility in supporting the learning process. The operational definitions of the variables for Heuristic Evaluation (HE) are presented in Table 3.

Table 3.

Operational Definition of Variables for Heuristic Evaluation (HE)

Dimension	Indicator	Code	Questionnaire Item
Visibility of system status	The system provides clear information about what is currently happening (e.g., loading, completed processes, or errors).	HE01	This media display clearly tells what is happening (e.g., loading or displaying results).
	The language and terminology used align with everyday		

User control and freedom	Options are available to undo or redo actions.	HE03	user understanding. understand, like everyday language. I can easily go back or cancel if I select the wrong menu/button. The location and shape of the buttons/menus in this media are consistent on every page.
Consistency and standards	The appearance and terms used are consistent throughout the system.	HE04	This media provides warnings or confirmation before taking important actions. I can find the features I need without having to remember previous steps.
Error prevention	The system prevents errors before they occur, such as by confirming important actions.	HE05	This media is easy to use for both new and experienced users. The appearance of this media is simple, neat, and not excessive. If an error occurs, this media provides an easy-to-understand message or instruction.
Recognition rather than recall	Users do not need to memorize steps to complete a task.	HE06	This media provides easy-to-access help or guidance.
Flexibility and efficiency of use	The design supports efficiency for both inexperienced and experienced users.	HE07	
Aesthetic and minimalist design	The visual design is appealing without interfering with core functionality.	HE08	
Help users recognize, diagnose, and recover from errors	The system guides to help users correct errors.	HE09	
Help and documentation	The system provides accessible help or documentation.	HE10	

G. Research Objectives

The authors aim to evaluate whether the interactive learning medium is useful and effective. This study does not test causal effects; rather, it demonstrates the effectiveness of each heuristic principle based on user perceptions. The objectives guiding the evaluation process are outlined in Table 4.

Table 4.
Research Objectives

No	Research Objectives
1	To evaluate the effectiveness level of the interactive learning media based on the visibility principle for system status.
2	To assess how well the system matches the real world in terms of language and concepts used in the media.
3	To analyze the level of user control and freedom provided within the interactive learning media.
4	To evaluate the consistency and standards of the interface design and functional elements.
5	To determine the effectiveness of error prevention and error recovery mechanisms in the system.
6	To assess the quality of aesthetic and minimalist design in Supporting the learning experience.

- 7 To evaluate the overall usability of the interactive learning media based on all 10 heuristic evaluation principles.

H. Validity Test

The purpose of the validity test is to ensure that each questionnaire item accurately measures the intended aspect. Validity testing was conducted by examining the correlation values between each question item and the overall score. If an item's correlation value exceeds the r-table value at the 0.05 significance level, it is considered valid. The test results show that all items have correlation values above the r-table, so all items are deemed valid and can be used for further analysis.

I. Reliability Test

The purpose of the reliability test is to assess the questionnaire's internal consistency. The test was conducted using Cronbach's Alpha, with the criterion that a variable is considered reliable if the alpha value is ≥ 0.70 . The test results show that Cronbach's Alpha for each variable is above this threshold, confirming that the research instrument is reliable and can be used in analysis.

J. Descriptive Test (Mean and Standard Deviation)

Descriptive analysis is used to obtain a general overview of respondents' responses to each questionnaire item in the Heuristic Evaluation variable. This analysis is conducted by calculating the mean and standard deviation (SD) to determine the level of tendency and consistency in respondents' answers. The results of this descriptive analysis then serve as the basis for assessing the extent to which the heuristic principles are applied in the evaluated system.

K. Analysis of Each Heuristic Evaluation Indicator

The results of each heuristic evaluation indicator were analyzed to interpret the respondents' assessments of Nielsen's ten heuristic principles. Each indicator was analyzed based on its mean value, thereby allowing the system's strengths and areas for improvement to be identified. This analysis provides an in-depth view of the system's usability from the user's perspective.

IV. RESULTS AND DISCUSSION

A. Implementation

The implementation phase is where the developed application is tested to ensure it runs properly on Android devices. In this study, the implementation results in an APK application file compiled with Adobe Animate. Implementation is carried out to display the final application containing all the main features. The following are the 10 final screens of the interactive learning medium:

1) Loading screen page

Figure 3 shows the loading screen, the opening page of the interactive learning medium. This screen displays the application logo and a loading bar, serving as a transition interface before directing users to the main page.



Fig. 3. Loading screen page.

2) Main page

Figure 4 shows the main page, which contains a "Start" button and two additional buttons present on each page: the audio and help buttons.



Fig. 4. Main page.

3) Menu Page

Figure 5 shows the menu page, which displays three main navigation buttons: the "About SDGs" button, the "17 SDGs Goals" button, and the "Quiz" button.



Fig. 5. Menu page.

4) About SDGs Page

Figure 6 displays the "About SDGs" page, which provides general information about the SDGs. The home button returns users to the menu page, and the next button directs them to the next page, which contains a brief history of the SDGs.



Fig. 6. About the SDGs page.

5) *17 SDGs goals page*

Figure 7 displays the "17 SDGs Goals" page, which consists of 17 SDG icons that serve as interactive buttons directing users to the explanation page for each goal. A next button is also provided to view other SDG icons.



Fig. 7. 17 SDGs goals page.

6) *Goal detail page*

Figure 8 shows the 'Goal Detail Page', which includes an animation representing each SDG goal and three buttons: 'Pendahuluan', 'Dampak', and 'Upaya', which allow users to navigate between different sections of the explanation.



Fig. 8. Goal detail page.

7) *Quiz introduction page*

Figure 9 shows the quiz introduction page, which includes brief instructions for taking the quiz and a "Start Quiz" button to begin.



Fig. 9. Quiz introduction page.

8) *Quiz page*

Figure 10 shows the quiz page, which displays a multiple-choice question and four answer options. Answers must be selected before proceeding to the next question.



Fig. 10. Quiz page.

9) *Quiz result page*

Figure 11 shows the quiz result page, which displays the user's final quiz score after completing 10 questions. The page also includes the number of correct and incorrect answers.



Fig. 11. Quiz result page.

10) *Help/documentation panel*

Figure 12 shows the help/documentation panel that appears when the help button is pressed. This panel provides usage information and guidance for the interactive learning medium.



Fig. 12. Help/documentation panel.

B. *Evaluation Result*

1) *Data collection results*

This study used a HE questionnaire comprising 10 items (HE01-HE10) to assess the effectiveness of the user interface in animation-based learning media. The measurement scale used was a Likert scale with five response levels, ranging from 1 (strongly disagree) to 5 (strongly agree). Data collection was performed through Google Forms and distributed to high school students as respondents. Based on the questionnaire responses, 200 respondents provided complete answers. The data collected included respondent profiles such as school, class, gender, and age, as well as previous experience with animation-based learning media. In addition, ten main questions represent the assessment indicators for the heuristic aspects (HE01-HE10). Each respondent's answer was converted to a numeric value on the Likert scale and then summed to obtain a total score for each HE item. This total score was then used as a basis for assessing the effectiveness of the developed learning medium. Before statistical analysis, the questionnaire data were checked to ensure completeness and consistency of responses. The results showed that all data entries were complete and met the requirements for further analysis. Therefore, the collected data were used for the next stage, namely, the respondent characteristics analysis, validity and reliability tests, descriptive analysis (mean, SD), and analysis of each heuristic evaluation indicator.

2) *Respondent characteristics*

This study involved high school students in Batam City across five sub-districts (Sekupang, Sagulung, Batam Kota, Nongsa, and Bulang). Data were collected using a cluster sampling technique, with 200 students as respondents. The characteristics of the respondents are summarized in three figures. Fig. 13 displays the distribution of respondents by school; Fig. 14 shows the distribution by gender; and Fig. 15 displays the distribution by grade level.

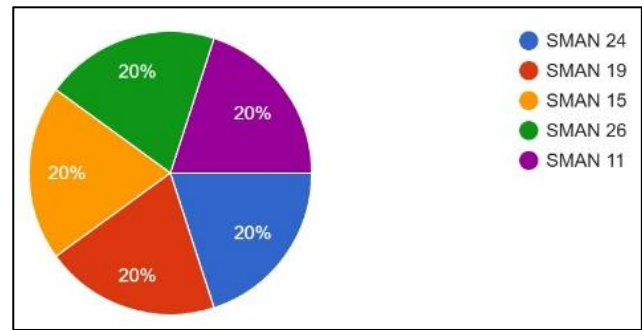


Fig. 13. Respondent characteristics based on school.

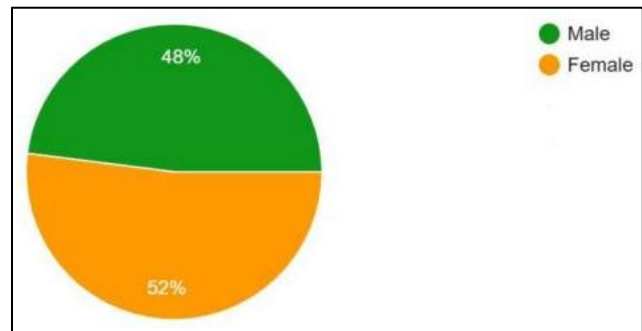


Fig. 14. Respondent characteristics based on gender.

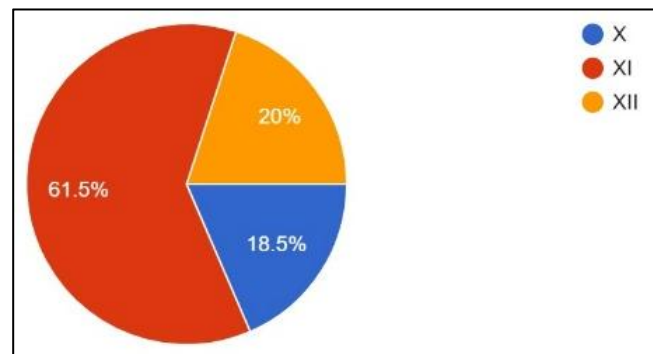


Fig. 15. Respondent characteristics based on grade level.

3) *Validity test*

Based on the results of the validity test using the Pearson Product-Moment correlation on the HE variable shown in Table 5, the correlation coefficient (r-count) between items HE01 to HE10 and the total score (HESUM) ranged from 0.425 to 0.776 with a significance value of $p < 0.05$. This fact indicates that all items are valid, as the r-count value exceeds the r-table value (0.138) and $p < 0.05$.

Table 5. Validity Test Results

Question Item	Pearson Correlation (r)	Sig. (2-tailed)	Description
HE01	0.584	< 0.001	Valid
HE02	0.748	< 0.001	Valid
HE03	0.739	< 0.001	Valid
HE04	0.762	< 0.001	Valid
HE05	0.425	< 0.001	Valid
HE06	0.454	< 0.001	Valid
HE07	0.726	< 0.001	Valid
HE08	0.776	< 0.001	Valid
HE09	0.726	< 0.001	Valid
HE10	0.776	< 0.001	Valid

4) Reliability test

Based on the reliability test results for the 10 items in the HE variable (Table 6), Cronbach's Alpha was 0.855. Therefore, all items in the Heuristic Evaluation variable are reliable, indicating that the questionnaire has high internal consistency and is suitable for research data collection.

Table 6. Reliability Test Results

Variable	Cronbach's Alpha	N of Items	Description
Heuristic Evaluation (X)	0.855	10	Reliable (High Reliability)

5) Descriptive Analysis (Mean and SD)

Based on the descriptive analysis shown in Table 7, the overall average score for the Heuristic Evaluation variable is 4.03, with a standard deviation of 0.87. These findings show that respondents generally gave a positive assessment of the heuristic aspects of the learning medium under evaluation. The item with the highest mean score was HE08 (4.42), indicating that respondents strongly agreed that this aspect was best implemented in the interactive learning medium. Meanwhile, the item with the lowest mean score was HE09 (3.69), which was still in the high category, indicating that all heuristic aspects were well implemented; however, error prevention (HE05) and the help users recognize, diagnose, and recover from errors principle (HE09) still have room for minor improvements to create a more optimal user experience.

Table 7. Descriptive Analysis Results

Question Item	Mean	Std. Deviation	Category
HE01	3.8517	0.86714	High
HE02	4.0622	0.79720	High
HE03	3.9809	0.88775	High
HE04	4.3589	0.75347	Very High
HE05	3.7212	0.99716	High
HE06	3.9426	0.88064	High
HE07	4.3876	0.75831	Very High
HE08	4.4211	0.76255	Very High
HE09	3.6938	0.98645	High
HE10	3.9569	0.91623	High
TOTAL HE	4.03	0.87	High

TABLE 8. AVERAGE SCORE INTERPRETATION CRITERIA

Score Range	Category
1.00–1.80	Very Low
1.81–2.60	Low
2.61–3.40	Moderate
3.41–4.20	High
4.21–5.00	Very High

6) Analysis of Each Heuristic Evaluation Indicator

Based on the results of the heuristic evaluation indicators shown in Table 9, the average value of 4.04 falls into the high category, indicating that users generally consider the system efficient and user-friendly. The highest-value indicator is HE08 (mean = 4.42), which falls into the very high category, indicating that respondents consider the system's visual design

to be the best implemented aspect. This fact suggests that users are at ease and encounter no major challenges when using the system. Furthermore, indicators HE04 (mean = 4.36) and HE07 (mean = 4.38) also fall into the very high category, indicating that the system has good consistency and efficiency. In contrast, indicators HE09 (help users recognize, diagnose, and recover from errors) and HE05 (error prevention) had mean scores of 3.69 and 3.72, respectively.

Both indicators are still in the high category but require the most improvement according to the score interpretation criteria. Specifically, HE05 scored lower because the system lacks a confirmation dialog, such as an "Are you sure?" prompt that appears when users press the "Home" or "Exit" buttons, which often causes users to lose their learning progress accidentally. HE09 scored lower because when users make errors in the quiz, the system displays a cross (X) without explaining the reason or how to correct it. Therefore, future improvements should focus on providing more informative error messages and adding features that protect user actions to reduce unintentional errors. Overall, the remaining indicators fall in the high category, including HE01, HE02, HE03, HE04, HE06, HE07, and HE10, indicating that the system has successfully met most of the heuristic evaluation principles, especially in terms of display consistency, usability efficiency, and clear user feedback. The standard deviation values, all below 1.0, also indicate that respondents' perceptions are relatively consistent across items.

Table 9. Descriptive Report for Each Heuristic Evaluation Indicator

Indicator Code	Mean	Std. Deviation	Category
HE01	3.85	0.86	High
HE02	4.06	0.79	High
HE03	3.98	0.88	High
HE04	4.36	0.75	Very High
HE05	3.72	0.99	High
HE06	3.94	0.88	High
HE07	4.38	0.75	Very High
HE08	4.42	0.76	Very High
HE09	3.69	0.98	High
HE10	3.95	0.91	High
Overall Average	4.04	0.89	High

C. Discussion

The evaluation results show that although the interactive learning medium achieved high overall usability scores, it still has several specific strengths and weaknesses. These findings reflect how design and development decisions at each stage of the MDLC impact the system's usability outcomes.

The highest score was obtained for the aesthetic and minimalist design principle (HE08), with a mean score of 4.42. These results indicate that the medium's visual appearance was very well received by users and supported their learning experience. The success of HE08 is directly related to the interactive learning medium design, which paid special attention to visual consistency, color harmony, and the selection of high-quality illustrations. Furthermore, subtle animations and a clean layout helped engage users while

presenting SDG-related content without placing excessive cognitive load. These findings align with the usability principle that well-designed visual elements can enhance user comprehension and satisfaction, particularly for high school students.

In contrast, the error prevention (HE05) and help users recognize, diagnose, and recover from errors (HE09) principles received the lowest mean scores, at 3.72 and 3.69, respectively. These results indicate that error handling remains a notable weakness in the system's usability. This limitation stems from the medium's focus on content delivery and visual aesthetics, with functional mechanisms for error prevention and recovery not prioritized. As a result, the system lacks confirmation dialogs, such as those for exiting the application, which can lead to unintentional navigation errors. Furthermore, when users make errors, particularly in the quiz section, the system only displays an error icon, with no clear explanation or guidance for correcting the error.

V. CONCLUSION

This research successfully developed "SDGs Adventure," an interactive Android-based learning medium using the MDLC method, which proved effective and comfortable for students based on heuristic evaluation results that rated its user interface as "High" with strong consistency. However, this study has limitations, including a descriptive usability evaluation without inferential analysis, a respondent pool limited to high school students that restricts generalizability, and identified interface weaknesses in error prevention and recovery (HE05 and HE09). Future work should therefore focus on enhancing the interface with animations and interactive effects, expanding the application to multiplatform support, combining quantitative and qualitative evaluation methods to address design weaknesses, and conducting experimental research to comprehensively measure the medium's impact on student learning outcomes.

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