Design and Development of an Educational Game for Learning Ecosystem Harmony Using the MDLC Method

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Abstract

Purpose: This study aimed to design and develop an educational game as an interactive learning medium to improve fifth-grade elementary school students' understanding of ecosystem harmony, particularly food chains and food webs, which are often difficult to understand through conventional learning methods.

Methodology/approach: This study was conducted at SD Negeri Sukorejo, Turi District, Lamongan Regency, involving 14 fifth-grade students. The educational game, HAMORA (Harmoni Ekosistem Rantai Makanan), was developed using the Multimedia Development Life Cycle (MDLC) method, which includes concept, design, material collection, assembly, testing, and distribution stages. Unity was used as the development engine, and the visual assets were designed using Canva. Data were collected through interviews and observation of classrooms. The evaluation consisted of Black Box testing, compatibility testing on various Android devices, usability testing using the System Usability Scale (SUS), and learning effectiveness testing through pre- and post-tests.

Results/findings: The results show that the application runs smoothly on multiple Android devices, and all features function properly. The usability evaluation achieved an average SUS score of 77.14, indicating an acceptable level with a good interpretation. The learning effectiveness analysis revealed an improvement in students' understanding, with N-Gain values categorized as moderate.

Conclusions: The HAMORA educational game was successfully developed as an interactive learning medium that enhances student engagement and understanding of ecosystem harmony.

Limitations: This study was limited to one elementary school and focused only on food chain and food web materials.

Contributions: This study provides a practical reference for implementing game-based learning in elementary education.

Keywords: *Educational Game, Food Chain, Multimedia Development Life Cycle (MDLC)*

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1. Introduction

In the current digital era, technology has brought significant changes in various aspects of life, including education. The use of technology as a learning medium is crucial, as learning media are an important variable in supporting the advancement of instructional content and can assist students in understanding materials more efficiently and engagingly (Sugiyanto, Pintakami, Sukesi, Nurhadi, & Fitriana, 2023). The appropriate integration of technology into learning can enhance students' motivation and learning effectiveness. At the elementary school level, Riyandana, An Ars, and Surahman (2022) explain that students tend to be more interested in and better able to remember communicative and enjoyable visual

or written content, particularly when presented in the form of simple games with bright colors and attractive animations.

Based on interviews conducted at SD Negeri Sukorejo, Turi District, students' learning interest was found to be relatively low. Elementary school is a critical stage in the early learning process. Although elementary education facilities are widely available, many students still experience difficulties in understanding learning materials and demonstrate low learning motivation due to boredom, fatigue, and lack of engagement (Windayati, Rozi, & Abdurahman, 2024). One of the learning topics that poses challenges for fifth-grade students is ecosystem harmony, particularly food chains and food webs. This material is often delivered using limited instructional variations, resulting in weak conceptual understanding and low retention rates.

Interactive learning media that utilize technology are required to address these problems. Educational games are considered effective alternatives because they can increase students' motivation and encourage active participation in learning. According to Prasetyo, Syaputra, Cholil, and Sauda (2021), educational games support learning by integrating knowledge, skills, and attitudes through gameplay mechanisms. Several previous studies have developed educational games using the Multimedia Development Life Cycle (MDLC) method; however, many of these studies have focused mainly on the development process and functional testing outcomes.

In many cases, usability evaluation using standardized instruments such as the System Usability Scale (SUS) is not conducted in a structured manner, and learning effectiveness is not measured quantitatively through pre- and post-test analysis. Consequently, empirical evidence regarding the impact of MDLC-based educational games on students' learning outcomes remains limited, particularly at the elementary school level. This study addresses these gaps by designing and developing an educational game for learning ecosystem harmony for fifth-grade elementary school students using the MDLC method, accompanied by usability testing, compatibility testing across Android devices, and learning effectiveness evaluation using pre- and post-tests. The proposed game is expected to function as an interactive learning medium that enhances students' understanding and retention of ecosystem harmony concepts, especially food chains and food webs, in an engaging environment.

2. Literature Review and Hypothesis Development
2.1. Related Studies
Previous studies have indicated that Android-based educational games are widely used as interactive learning media for elementary school students. Khaerudina, Srisulistiowatib, and Wartac (2014) developed a Unity-based educational game that supported classroom learning and increased students' interest. Similar findings were reported by Prasetyo et al. (2021) and Nugraha (2022), who showed that two-dimensional Android educational games positively contributed to students' learning motivation and conceptual understanding. Although these studies confirm the potential of educational games in elementary education, most of them primarily emphasize motivational aspects and general learning outcomes, while usability evaluation and systematic measurement of learning effectiveness have received limited attention.

International studies further reinforce the evidence for the effectiveness of technology-enhanced and game-based learning environments. Zheng, Zhong, Niu, Long, and Zhao (2021) demonstrated that personalized interventions in computer-supported collaborative learning significantly improved group performance, collaborative knowledge building, and metacognitive regulation while managing learners' cognitive load, highlighting the importance of well-designed digital learning support. In the context of educational games, Peng, Song, Kim, and Day (2016) found that task demand and social diversity within a language learning game significantly influenced learners' performance and enjoyment, indicating that gameplay design plays a crucial role in learning effectiveness. Similarly, Wood and Donnelly-Hermosillo (2020) reported that electronic games were at least as effective as traditional study guides in supporting students' mastery of chemistry nomenclature, suggesting the potential of digital games to enhance conceptual understanding in chemistry.

Beyond games, immersive digital environments also show promise Chen, Hung, and Yeh (2021) revealed that virtual reality–based problem-based learning significantly improved learners' problem-solving performance, vocabulary acquisition, and motivation. However, despite these positive findings, prior studies have largely emphasized learning outcomes and comparative effectiveness, with relatively limited attention to usability evaluation and classroom-based implementation, particularly at the elementary education level. From a development methodology perspective, several studies indicate that the Multimedia Development Life Cycle (MDLC) is suitable for developing educational games. Rizal, Mursalim, and Kamaruddin (2019) emphasized that MDLC provides structured and sequential stages that support the development of multimedia-based learning media. Studies conducted by Fortuna, Purnamasari, and Dikananda (2023) and Nisya, Wulansari, and Wartariyus (2023) also applied the MDLC method and concluded that it effectively produced interactive learning applications. However, these studies tend to concentrate on the development process and functional feasibility, while comprehensive evaluations involving standardized usability instruments and quantitative learning effectiveness analyses remain limited.

In the context of ecosystem learning, Wibowo, Simaremare, and Yus (2022) developed an Android-based educational game to introduce ecosystem concepts and reported improved student understanding of the subject. Istyasiwi, Aulianty, and Sholeh (2021) developed digital learning media on food chains and found positive effects on student comprehension; however, the level of interactivity and empirical evaluation of learning effectiveness were still relatively minimal. These limitations indicate the need for more interactive learning media that not only present ecosystem material visually but also evaluate usability and learning outcomes in a measurable manner.

Based on the identified gaps, this study focuses on developing an Android-based educational game on ecosystem harmony, particularly food chains and food webs, using Unity and the Multidisciplinary Design Course (MDLC) method. Unlike previous studies, this research integrates usability evaluation using the System Usability Scale (SUS), compatibility testing across different Android devices, and learning effectiveness assessment through pre- and post-test analyses. This approach is expected to provide a more comprehensive contribution to the development and evaluation of educational games as science learning media at the elementary-school level.

2.2. Theoretical Framework

2.2.1. Game
A game is an activity played according to specific rules to provide enjoyment and a relaxed playing experience. According to experiences designed as entertain experiences, or provide certain experiences to players through various predetermined mechanisms and rules. In addition to serving as entertainment for leisure time, games can also be utilized as educational and training media that support the learning process through interactive and enjoyable approaches (Kalaka, Mustofa, & Dalai, 2023).

2.2.2. Educational Games
Educational games are designed for learning purposes while still offering elements of play and enjoyment, integrating educational content, learning principles, and computer game technology (Nisya et al., 2023). According to Kurniawan, Paramesvari, and Purnomo (2021), educational games aim to stimulate thinking skills, enhance concentration, and train problem-solving abilities. In addition, educational games are developed by considering learning principles so that players can acquire new knowledge and skills through their gameplay experiences. The use of educational games can increase learning motivation, create an enjoyable learning atmosphere, and help strengthen students' understanding of the concepts being studied (Luay, Asriyanik, & Apriandari, 2024). Filashofia and Usman (2025) also note that educational games can reinforce memory and comprehension through engaging and interactive learning experiences.

2.2.3. Learning Ecosystem Harmony
Ecosystem harmony is a science subject taught in the fifth grade of elementary school that discusses the interrelationships and balance among the components within an ecosystem. Ecosystem harmony refers to a condition in which all living organisms and environmental components interact in a balanced

and mutually supportive manner (Ghaniem, Rasa, Oktora, & Yasella, 2021). An ecosystem is a natural system that involves interactions between living (biotic) components, such as plants, animals, and microorganisms, and nonliving (abiotic) components, including water, soil, and air (Farhan, Setiawan, & Az-Zahra, 2024).

According to Mewengkang, Tangkawarow, and Kasehung (2018), an ecosystem contains species diversity within a community and its environment, functioning as a unified system of life interaction in nature. The concept of ecosystem harmony can be understood through food chains and food webs, which illustrate the flow of energy from producers to consumers and demonstrate that disturbances in one component can affect the entire ecosystem. However, because this concept is abstract and requires systemic understanding, learning delivered solely through verbal explanations or text-based materials is often less effective and may lead to confusion among students.

2.2.4. MDLC Method
The Multimedia Development Life Cycle (MDLC) is a method for multimedia development used in designing and creating applications that involve various types of media such as images, audio, video, and animations. This method consists of six stages: concept, design, material collection, assembly, testing, and distribution (Kurniawan et al., 2021). The concept stage aims to identify the objectives and target users, whereas the design stage focuses on interface design and visual elements. The material collection stage involves gathering all the required multimedia assets, followed by the assembly stage, in which these materials are integrated to create a functional system. Subsequently, the testing stage is conducted to ensure that all features operate as intended, and the distribution stage represents the final phase, which includes the evaluation and delivery of the application to users. According to Wardana and Armin (2025), this method is effective in developing interactive applications or learning media.

2.2.5. Game Design Document
A Game Design Document (GDD) is a document that provides a detailed explanation of the design and development process of a game, including educational games or game-based learning applications (Arifudin, Suliswaningsih, Pramesti, & Heryanti, 2022). This document serves as the primary guideline for game development, encompassing the game concept, gameplay flow, interaction mechanisms, and visual design, thereby ensuring that all game components are developed systematically and aligned with predetermined objectives.

2.2.6. Unity Engine
Unity is a game development software widely used among digital game developers, including for educational games, as it supports the development of both 2D and 3D games effectively. According to Khaerudina et al. (2014), Unity is a game development platform that provides a user-friendly interface and supports a wide range of development features. In addition, Unity is equipped with a diverse asset collection and supports scripting using the C# programming language, enabling developers to build cross-platform applications with optimal performance and efficiency.

2.2.7. C# Programming Language
C# is an object-oriented programming language developed by Microsoft and is widely used to develop various types of applications, including games. In game development using Unity, C# serves as the primary programming language because of its efficiency, flexibility, and ease of understanding. In addition to having a syntax similar to other programming languages, such as C++ and Java, C# is well integrated with the Unity platform, thereby optimally supporting the application development process (Farhan et al., 2024).

2.2.8. Two-Dimensional Objects
Two-dimensional (2D) objects possess only two dimensions, namely length and width, without depth, and are therefore viewed on a flat surface. In digital application development, two-dimensional (2D) objects are widely used in graphic design, animation, and interactive applications. The construction of 2D objects is based on Cartesian coordinates along the X- and Y-axes. In game development, 2D refers to games created with flat graphical displays that typically use two-dimensional images for characters,

backgrounds, and other elements (Sulaiman & Mamay, 2025). The use of two-dimensional objects in educational games aims to present visuals that are simple, easy to understand, and aligned with the characteristics of children as the primary target users of learning applications.

2.2.9. Blackbox Testing

Black box testing is a testing method that focuses on the predetermined features and functions of software, in which testers identify the input conditions and evaluate the program based on its functional specifications (Rusmana, Asriyanik, & Setiawan, 2023). This testing emphasizes the conformity of the output produced with the given input to ensure that all game functions operate as intended and meet the users' expectations (Kurniawan et al., 2021).

2.2.10. System Usability Scale (SUS)

The System Usability Scale (SUS) is an evaluation method used to measure the usability level of a system through a questionnaire consisting of ten items with five response options (Susila & Arsa, 2023). The SUS score is calculated by subtracting 1 from the scores of the odd-numbered items, while for the even-numbered items, the score is subtracted from five. The results were then summed and multiplied by 2.5 to obtain the final SUS score. The average SUS score was calculated from all respondents and served as a benchmark for evaluating the quality of the user experience and the overall ease of use of the system. The SUS testing results produce a score that is subsequently classified into specific categories, such as "acceptable" or "excellent," based on the percentage and interpretation of the score (Dias, Enstein, & Manu, 2021).

3. Research Methodology

3.1. Type and Research Method

This study is a development research focusing on the creation of an interactive learning medium in the form of an Android-based educational game. The developed learning media aim to support elementary school students in understanding the concept of ecosystem harmony, particularly food chains and food webs. The system development method applied in this study is the Multimedia Development Life Cycle (MDLC), which consists of six stages: concept, design, material collection, assembly, testing, and distribution (Kurniawan et al., 2021). This method was selected because it provides a systematic and structured development process and is suitable for multimedia-based applications that integrate visual elements, audio, animations, and user interaction.

3.2. Research Subjects and Object

The subjects of this study were 14 fifth-grade students from SD Negeri Sukorejo, located in the Turi District, Lamongan Regency. The number of participants was determined based on the total number of students enrolled in the only fifth-grade class at the school, making the entire class the research sample for this study. This approach was chosen to ensure that all students directly involved in learning the relevant material participated in the study. Fifth-grade students were selected because ecosystem harmony, particularly food chains and food webs, is a core topic in the fifth-grade elementary-school science curriculum. In addition, students at this level are generally in the concrete operational stage of cognitive development, which requires visual, interactive, and contextual learning media to support effective understanding.

Therefore, the selected subjects were considered appropriate and relevant for evaluating the usability and learning effectiveness of the developed educational game. The object of this study was the educational game HAMORA (Harmoni Ekosistem Rantai Makanan), developed as an Android-based learning medium. The game presents learning materials through interactive activities, such as arranging food chain sequences and identifying predator–prey relationships, allowing students to learn through direct interaction and play.

3.3. Data Collection Techniques

Data were collected through interviews and classroom observations. Interviews were conducted with fifth-grade teachers to obtain information regarding teaching methods, challenges in delivering ecosystem-related materials, and the need for more engaging and interactive learning media to deliver

ecosystem-related materials. The interview results were used as a foundation for determining the application concept, features, and game mechanics. Classroom observations were conducted to examine the learning process, students' concentration levels, and their responses to the existing learning media. The results indicated that conventional teaching methods with limited visualization tend to reduce student engagement, reinforcing the need for interactive learning tools that promote active participation.

3.4. Application Development Stages

The development of the HAMORA educational game was carried out by following the stages of the MDLC method as follows.

1. Concept
   This stage focused on determining the objectives of application development, target users, the scope of learning materials, and the basic game concept. The game was designed as an interactive learning medium that is easy to use for elementary school students and is aligned with the characteristics of the target users.

2. Design
   The design stage was conducted by referring to the Game Design Document (GDD) as the primary design guideline for the game. The GDD contains the game concept, learning objectives, navigation flow, gameplay mechanics, user interface design, and the main features to be implemented in the game. The GDD was prepared to ensure that the application development process proceeded in a structured and consistent manner while remaining aligned with the intended learning objectives.

3. Material Collecting
   At this stage, various supporting materials were collected, including visual assets, images, icons, and audio elements related to food chains and food webs. All materials were adapted to the characteristics of elementary school students to optimally support their learning process.

4. Assembly
   The assembly stage involved the implementation of the design and assets into Unity. All application elements were integrated, including navigation flow settings, gameplay mechanics, and user interactions, in accordance with the design specified in the Game Design Document (GDD).

5. Testing
   The testing process was conducted to ensure that the application functions properly and can be effectively used as a learning medium for the target audience. This stage included functional evaluation, compatibility testing, and usability and learning effectiveness assessments. The results of this testing phase were used to identify potential improvements and verify that the application met the intended learning objectives and user requirements.

6. Distribution
   The distribution stage involves deploying the application so that it can be used by students as a supplementary learning medium in a school environment. This stage also serves as a basis for the evaluation and further development of the application in subsequent phases.

3.5. Testing Techniques and Data Analysis

Application testing was conducted using several methods. To evaluate the functionality of the application, a black box testing method was applied to ensure that each feature operated as intended without involving the internal code structure. In addition, compatibility testing was performed to ensure that the application functioned properly on various Android devices with different specifications and screen sizes. The purpose of this testing was to examine the consistency of the user interface display, ease of using the features, and overall performance of the application across multiple versions of the Android operating system.

Usability testing was conducted using the System Usability Scale (SUS) approach to assess ease of use, user comfort, and user satisfaction after interacting with the application. Students completed the SUS questionnaire after using the application. Learning effectiveness was evaluated using pre- and post-test methods. A pretest was administered before students used the application to measure their initial knowledge, while a post-test was given after application use to determine the extent of improvement in

their understanding of the learning material. The improvement in learning outcomes was analyzed using the N-Gain calculation to determine the effectiveness of the HAMORA educational game as an interactive learning tool.

4. Results and Discussions

The Results and Discussion section presents a logical and scientific analysis of the research findings. Evidence is provided to support the analysis by referring to relevant studies and theoretical frameworks. If tables and figures are included, they should follow the prescribed format: table titles and sources are aligned to the left, tables are centered, only horizontal lines are used for the outer borders of the tables, and no vertical or internal horizontal lines are used.

4.1 Interface Implementation

The interface design was developed in a simple manner, utilizing clear icons, attractive colors, and intuitive navigation to ensure that users could interact with the application without difficulty. This approach aims to enhance the user's comfort throughout the learning process.

Figure 1. Home Page

Figure 1 illustrates the home screen, which is the initial display when the app is launched. On this screen, users are greeted with a bright, nature-themed, visual design that is appealing to children. At the center of the screen, the application title HAMORA (Harmony of Ecosystem Food Chains) is displayed in bold, red capital letters to capture users' attention. Directly below the title, an orange "START" button is provided to direct the user to the main menu page. The home screen background features elements such as trees, terrestrial and marine animals, and a bright sun, representing a harmonious ecosystem.

Figure 2. Main Menu

Figure 2 presents the main menu page, which contains three primary option buttons.
1. Materials that function to display learning content related to food chains and food webs.
2. Arrange Food Chain, which is used for games involving the arrangement of food chain sequences and quizzes.
3. Eat or Be Eaten is used for the eat-or-be-eaten game.

The background of the main menu page adopts a nature-themed design, with illustrations of trees, animals, and other environmental elements. This background selection aimed to maintain visual consistency across pages while reinforcing the ecosystem concept presented in the application. Each button was designed with a bright orange color, rounded shape, and sufficiently large size to ensure easy recognition by users, particularly children. The use of bright colors also creates a cheerful and friendly impression, thereby increasing users' interest in interacting with the app.

Figure 3. Learning Content Menu Page

Figure 3 shows the learning content menu page, which serves as an introduction for users to select the learning topic to study. This page is divided into two main sections: the Food Chain on the left side and the Food Web on the right side. Each section is equipped with engaging visual illustrations to help users understand the basic concepts more easily and attract their interest in exploring the learning materials further. Orange buttons labeled "Food Chain" and "Food Web" allow users to access more detailed explanations of each topic. The layout of this page was designed to be simple and intuitive, ensuring that users, particularly elementary school students, can navigate the learning content comfortably and without confusion.

Figure 4. Food Chain Learning Page

Figure 4 displays the Food Chain learning page, which presents illustrations of relationships among animals such as grasshoppers, frogs, and snakes. At the bottom of the page, explanatory text describes the concept of food chains and the importance of maintaining balance among living organisms within an ecosystem. This display is designed to help children understand the concept visually through images, while simultaneously reinforcing their theoretical understanding through textual explanations. The combination of visual and textual elements supports students' comprehension and retention of learning materials. Additionally, a "Back" button is available at the bottom of the page, allowing users to easily return to the learning content menu page.

Figure 5. Player Name Entry Page

Figure 5 shows the player name entry page, which allows users to enter their names through a designated input field. This feature is intended to personalize the user experience and record user identification during gameplay. At the bottom of the page, a "Start" button is provided to proceed to the game's main page. In addition, a "Back" button is available at the upper left corner of the screen, allowing users to return to the previous page, if needed. The layout of this page was designed to be simple and clear, ensuring that users could easily input their names and navigate the application without difficulty.

Figure 6. Food Chain Construction Menu Page

Figure 6 shows the ecosystem location menu page. On this page, users can select one of six available ecosystem locations: Sea, Garden, Forest, Savanna, Rice Field, and River. Each ecosystem location button is designed with bright colors and illustrative visuals to make it attractive and easily recognizable for children. In addition to supporting user engagement, this design helps users quickly identify and select their desired learning environment. After players complete the game and answer all quiz questions in a selected ecosystem location, the system stores relevant data, including the player's name, selected ecosystem location, and score. This stored data can be accessed by pressing the trophy icon on the ecosystem location menu page, allowing users to review their performance and track their progress in the game.

Figure 7. Food Chain Arrangement Game Page

Figure 7 shows the core page of the Arrange Food Chain game. On this page, users are required to arrange the sequence of a food chain by dragging animals into the correct positions within the question mark circles. The game interface displays several marine animals, such as starfish, small fish, large fish, sharks, and shellfish, which must be arranged according to the predator–prey relationships. The interaction is carried out using a drag-and-drop mechanism to ensure ease of use for children. At the bottom of the screen, a "Check Answer" button is provided to verify the correctness of the arranged food chain. This button can only be accessed once all question mark circles have been filled, a condition implemented to ensure that players complete the entire sequence before checking their answers. This game is designed to train students' understanding of food chain concepts through an interactive and enjoyable learning experience that includes a quiz.

Figure 8. Evaluation Quiz Page

Figure 8 shows the food chain quiz page. This page serves as a learning evaluation component designed to measure the users' understanding after completing the Arrange Food Chain game. Players access the quiz section after successfully arranging the three food chain sequences. On this page, users were presented with 15 questions related to food chain and food web concepts, which had to be answered sequentially. Each time a user answered a question, the system automatically displayed the next question in a randomized order. In addition, the system is equipped with different sound effects for correct and incorrect answers, which are intended to enhance engagement and interactivity during quizzes. This evaluation feature supports the reinforcement of learning outcomes while maintaining a fun and motivating experience for users.

Figure 9. Quiz Score Page

After completing all the quiz questions, a score result panel appears, as shown in Figure 9. This panel displays the number of correct and incorrect answers and the final score obtained by the user. At the bottom of the panel, a "View Answers" button was provided. When this button is selected, users are directed to the answer review page, where they can examine the questions and corresponding answers in more detail.

This score result page functions as immediate feedback on quiz performance, allowing users to reflect on their learning outcomes. By providing clear and direct feedback, this feature reinforces understanding and encourages users to improve their performance in subsequent learning activities.

Figure 10. Eat or Be Eaten Gameplay Page

The gameplay page displayed a game board where animals moved toward the left side of the screen. As shown in Figure 10, users are required to determine the relationships among living organisms by selecting the appropriate predator in response to the prey that appears on the board. At the top of the screen, a life indicator in the form of three heart icons represents the player's remaining chances in the game. Additionally, an "Eaten" counter is displayed to indicate the number of prey successfully consumed by the predator. In the upper right corner of the screen, three main buttons are provided: a help button (question mark icon) to display information about predator animals, a pause button to temporarily stop the game, and a music button to control background music. At the bottom of the screen, a row of animal icons represents the available predators. Players can select one of these predators to place on the game board. This gameplay design encourages active decision-making and reinforces students' understanding of predator–prey relationships in an interactive and engaging way.

4.2 Application Testing

Application testing was conducted to evaluate the functionality, usability, and learning effectiveness of the HAMORA game. Functional testing was performed using the black-box testing method to ensure that each feature and menu in the application operated according to the predetermined design specifications. The testing results indicated that all application functions ran properly without any issues that could interfere with usability of the app. In addition, compatibility testing was performed to ensure that the application could operate on various smartphone devices with different specifications. The results of the compatibility testing demonstrated that the application functioned well across a range of tested devices, indicating that the game is suitable for use on various Android platforms.

Table 1. Results of SUS Evaluation

Respondent	Question										Value
	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	
R1	4	1	4	1	5	2	5	1	4	5	80
R2	3	1	4	3	4	2	5	1	3	4	70
R3	3	2	4	1	5	1	5	1	5	4	82.5
R4	4	1	4	1	4	1	5	1	4	5	80
R5	3	2	4	2	5	2	4	2	4	4	70
R6	4	1	4	4	5	1	5	2	5	2	82.5
R7	3	1	5	2	5	2	5	1	4	3	82.5
R8	3	3	4	5	5	1	4	3	4	4	60
R9	3	1	4	4	5	1	5	1	4	5	72.5
R10	4	1	4	3	5	1	5	1	5	4	82.5

R11	4	1	5	4	5	2	5	1	5	5	77.5
R12	5	1	5	1	5	5	5	1	5	5	80
R13	3	2	4	3	5	2	5	1	4	5	70
R14	5	1	4	1	5	1	5	1	5	4	90
Average											**77.14**

Usability testing was conducted using the System Usability Scale (SUS) to evaluate the ease of use and user acceptance of the application. The results, as presented in Table 1, show an average SUS score of 77.14, which falls into the *Good* and *Acceptable* categories. According to usability theory, an application with a SUS score above 68 is generally considered usable and acceptable for end users, indicating that the HAMORA educational game meets the fundamental usability standards for interactive learning applications. From an educational perspective, usability plays a significant role in supporting effective learning. An application with good usability can reduce cognitive load, allowing students to concentrate on learning content rather than system navigation. This aspect is particularly important for elementary school students, who are in the concrete operational stage and benefit from learning media that are simple, intuitive, and visually clear. The obtained SUS score reflects that the application interface, navigation structure, and interaction flow were designed in accordance with user-centered design principles.

These findings are consistent with previous studies on educational games, which indicate that applications with good usability tend to enhance student engagement and learning motivation. Clear navigation, responsive interactions, and functional features encourage students to interact more actively with the learning content, thereby supporting the learning process. Despite the positive usability results, the SUS score also indicates that certain interface elements and interaction mechanisms can be refined to further improve the user experience. The results of the usability evaluation indicated that the HAMORA educational game is appropriate for use as an interactive learning medium. The findings also suggest potential directions for future development aimed at improving interface consistency and interaction efficiency, which may lead to higher usability outcomes in future evaluations.

Table 2. Results of pretest and post-test

No	Respondent	Pre	Post	N-Gain	Category
1	R1	75	85	0.4	Middle
2	R2	65	90	0.71	High
3	R3	75	95	0.8	High
4	R4	65	75	0.29	Low
5	R5	50	75	0.5	Middle
6	R6	90	90	0	Low
7	R7	65	70	0.14	Low
8	R8	65	80	0.43	Middle
9	R9	55	75	0.44	Middle
10	R10	65	85	0.57	Middle
11	R11	85	95	0.67	Middle
12	R12	70	85	0.5	Middle
13	R13	90	90	0	Low
14	R14	50	75	0.5	Middle
Total		**965**	**1165**		
Average		**68.93**	**83.21**		
Average N-Gain				**0.425 = 42.50%**	

Learning effectiveness testing was conducted using a pretest–post-test design to evaluate the impact of the developed educational game on students' understanding of ecosystem harmony concepts, particularly food chains, and food webs. A total of 20 multiple-choice questions were administered to 14 fifth-grade students before and after using the application. This method was applied to measure changes in students' conceptual understanding resulting from the learning interventions. Based on the results presented in Table 2, the students' average score increased from 68.93 in the pretest to 83.21 in the post-test. This improvement indicates a positive change in students' understanding after using an interactive learning application. Referring to the N-Gain classification proposed by Hake (1998), the average N-Gain value of 0.425 falls into the moderate category. The normalized N-Gain was used to measure the degree of learning improvement by considering students' initial knowledge levels.

According to Nari, Akmay, and Sasmita (2020), N-Gain values are classified into low, moderate, and high categories, allowing a standardized interpretation of learning effectiveness. From a learning theory perspective, the moderate N-Gain result can be explained through constructivist learning theory, which emphasizes active learner involvement in knowledge construction. The interactive features of educational games, such as task-based activities and immediate feedback, encourage students to actively engage with the learning content. This learning approach aligns with the principles of game-based learning, which has been shown to support improved understanding and retention of learning materials in elementary education. These findings are consistent with previous studies reporting that educational games can effectively enhance students' learning outcomes when learning activities promote interaction and cognitive engagement. The integration of instructional content with game mechanics supports students in understanding abstract concepts more effectively than conventional learning methods.
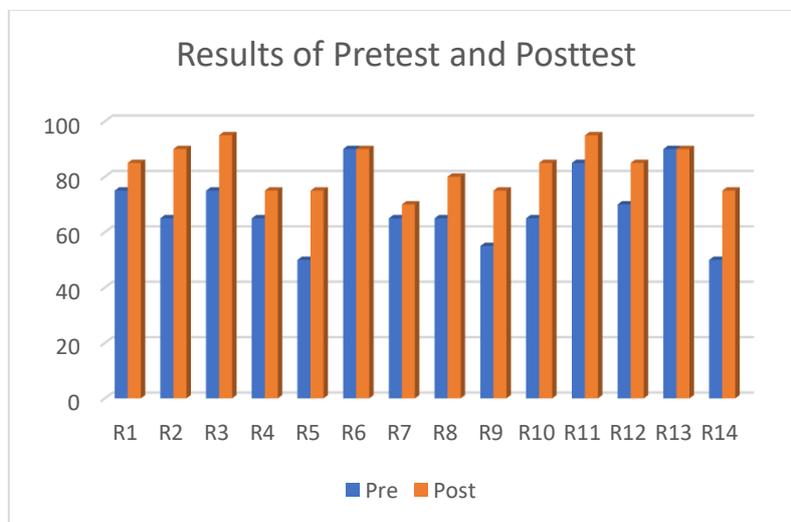

Figure 11. Pretest and Post-test Comparison Diagram

The comparison of pretest and post-test scores shown in Figure 11 further supports this finding, as most students demonstrated higher post-test than pretest scores. This result indicates that the HAMORA educational game is effective as a supplementary learning medium and contributes positively to improving students' conceptual understanding of ecosystem harmony.

4.3 Distribution
The distribution stage was conducted after the HAMORA educational game successfully completed the development and testing phases. At this stage, the application was published so that it could be accessed and utilized by users as a supporting learning medium for the course. The HAMORA educational game was distributed through the itch.io platform to facilitate its dissemination and improve accessibility for users. The published version of the application can be accessed via the following link: https://syafninisa.itch.io/hamora. Distribution through the itch.io platform is expected to support the use of the HAMORA educational game as a learning medium in school environments and for independent learning by students. In addition, the distribution stage provides opportunities to obtain

user feedback, which can be used as a basis for further evaluation and future development of the application.

5. Conclusions

5.1 Conclusion
This study successfully developed the HAMORA educational game as an interactive learning medium aimed at improving fifth-grade students' understanding of ecosystem harmony, particularly the concepts of food chains and food webs. The development process followed the Multimedia Development Life Cycle (MDLC), ensuring systematic implementation from concept design to distribution. The application was developed using the Unity engine on the Android platform, offering interactive visual features aligned with the learning objectives. Evaluation results indicate that the application is both feasible and effective. Black box testing confirmed that all system features functioned properly, while the System Usability Scale (SUS) yielded an average score of 77.14, reflecting good usability and positive user acceptance. The learning effectiveness assessment showed improvement in students' understanding, with the N-Gain categorized as moderate. These findings demonstrate that HAMORA has strong potential to support engaging and interactive science learning at the elementary level.

5.2 Research Limitations
Despite the positive outcomes, several limitations were identified. First, the learning materials were limited to specific ecosystem topics, which may restrict the scope of knowledge acquisition. Second, the number of respondents involved in testing was relatively small, limiting the generalizability of the findings. Third, the application is currently available only on the Android platform, which may reduce accessibility for users on other operating systems.

5.3 Suggestions and Directions for Future Research
Future research should expand the learning content to include additional ecosystem topics in order to enhance the educational value of the application. Increasing the number and diversity of respondents in subsequent studies is recommended to obtain more representative results regarding usability and learning effectiveness. Furthermore, developing versions of the application for other platforms, such as iOS or web-based environments, would improve accessibility and scalability. Researchers are also encouraged to conduct longitudinal studies to evaluate long-term learning impact and to explore integration strategies within classroom curricula to maximize HAMORA's role as an effective complementary learning tool.

Author Contributions
SNA contributed to conceptualization, study design, data collection, data analysis, manuscript drafting, and final approval of the manuscript. APA contributed to methodological supervision, critical revision of the manuscript, validation of results, and final approval of the manuscript. Both authors have read and agreed to the published version of the manuscript.

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