Development of the Riverkeeper Game Using Canva Application to Teach Ecosystem Topic to High School Students

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Abstract

Ecosystem learning in secondary education often relies on theoretical instruction with minimal contextual engagement, leading to persistent misconceptions and low student understanding. This study aims to address this pedagogical gap by developing the Riverkeeper game, an innovative hybrid learning media that combines digital platforms (Canva, Wordwall, and Google Docs) with field exploration activities to support ecosystem instruction. Using a modified 4D development model (Define, Design, Develop, Disseminate) but only Define, Design and Develop stages were conducted in this paper. Data were collected from five biology teachers and twenty Grade 11 students to identify instructional challenges and needs. The Riverkeeper game was designed based on constructivist and experiential learning principles, integrating digital problem-solving tasks with real-world observation of river ecosystems. The media prototype underwent expert validation involving three evaluators (a biology education lecturer, a media expert, and a senior high school biology teacher) using a structured instrument covering three aspects: game guidance, visual communication and design, and functionality. Validation results showed an overall score of 88% (very valid), with strengths in instructional clarity and visual design, though minor revisions were suggested for navigation and technical integration. A practicality test involving twenty students reported high satisfaction and relevance to learning objectives. As this study focused solely on the development and validation stages, further research is recommended to evaluate the game's effectiveness in improving student learning outcomes. The Riverkeeper game presents a novel approach to ecosystem education by integrating digital game-based learning with direct environmental exploration.

Keywords: Ecosystem; The Riverkeeper; Canva; Game Based Learning

INTRODUCTION

Ecosystem understanding is a fundamental aspect of Biology education, reflecting the dynamic, reciprocal relationships between organisms and their environments (Odum & Barrett, 2005; Schizas et al., 2018). Indonesia, a mega-biodiverse nation with varied ecosystems, from tropical rainforests to coastal and mountainous regions, faces critical environmental challenges. Nevertheless, formal environmental education in schools has yet to yield satisfactory outcomes in ecological literacy (Situmorang & Tarigan, 2018). Strengthening ecosystem content within Biology curriculum is therefore essential for nurturing ecological awareness from a young age (Sterling, 2014).

However, studies reveal persistent student difficulties in grasping ecological concepts, often leading to low achievement and misconceptions (Razak et al., 2022; Purwanti & Kuntjoro, 2020). Difficulties in learning ecosystem are often examine because the topics are complex, like the students need to link an ecosystem component one to another and suggest ideas to keep the ecosystem balanced (Mambrey et al., 2022). This could be the effect of the teaching method that used by teachers. Most of the teachers are teaching the ecosystem topic indoors in the classroom, so the students can not connect the topic to the real environment and may not add any value to students' learning in science (Ayotte-Beaudet et al., 2023). Traditional lectures that held indoor in the classroom were considered boring by the students. Educational games seem to be an alternative in providing learning that is not boring, It appears that learning becomes significantly easier when students are engaged in enjoyable activities like playing games, compared to when they are required to sit still and focus solely on formal instruction (Kinchin, 2018). Outdoor activity can foster students understanding about ecosystem in a fun way. For instance, middle-school students taught through game-based activities showed significant gains in understanding ecosystem concepts, demonstrating the potential of interactive and contextual pedagogies (Lasala Jr., 2023). Then, in today's learning, technology is one of the main factors that support learning. Educational technology has three domains of use, namely 1) technology as a tutor (computers provide instructions and guide users), (2) technology as a teaching aid, and 3) technology as a learning aid (Stosic, 2015). In this paper, the use of technology is plan to be a learning aid, supporting an outdoor activity in ecosystem learning. These findings highlight both a conceptual gap and an opportunity for pedagogical innovation.

River ecosystems, such as Indonesia's Citarum River in West Java, exemplify urgent, locally relevant ecological issues. Despite its critical role in irrigation, water supply, and reservoir systems, Citarum has been labeled among the world's most polluted rivers (Sholeh et al., 2018; Setianti et al., 2019). This urgency underscores the need for instructional materials that link environmental content with real-world river contexts.

Although various educational games about ecosystem like *Betty's Brain* have been developed, most remain confined to digital simulations, lacking integration with local field experiences. The Betty's Brain has demonstrated improvements in students' causal reasoning and self-regulated learning, particularly in river ecosystem topics. Yet, its purely digital nature limits its applicability in physically contextualized learning environments. This paper introduces '*The Riverkeeper*', an educational game that merges digital mechanics (created via Canva and Wordwall) with authentic, local field experience at Citarum River. This hybrid approach addresses three key novelties:
1. Digital design based on Canva and Wordwall, offering intuitive content creation and engagement.
2. Contextual specificity, focusing on the Citarum River and aligned with students' lived environments.
3. Hybrid format, combining online gameplay, in-person field observation, and authentic ecosystem interaction.

The study follows the 4D model (Define, Design, Develop, Disseminate) for educational media development (Thiagarajan et al., 1974). At this stage, we focus on

media development and validation only, deliberately excluding learning outcome measurement, an area for future research. The objectives of this study are to develop a hybrid-format ecosystem game applicable to Biology learning, validate the game's design and content via expert review and practicality testing, and bridge the literature gap by integrating digital, local, and experiential learning in a single educational tool.

METHOD

Research Design

This study employed a Research and Development (R&D) approach to develop The Riverkeeper educational game, adopting the 4D development model (Thiagarajan et al., 1974; Indartanti et al., 2023). The 4D model consists of four sequential stages: Define, Design, Develop, and Disseminate. However, the present research was limited to the Develop stage, focusing on product development, expert validation, and a practicality test with a group of students. The overall methodological flow of the study is summarized in Figure 1.
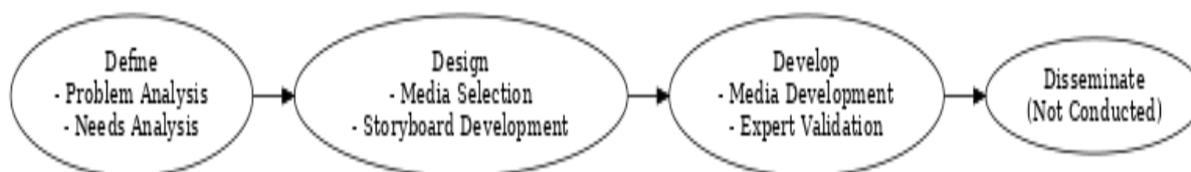

Figure 1. Summary of Methodological Flow

Participants and Sampling

Participants for the define and validation stages were selected using purposive sampling based on specific inclusion criteria. The student participants consisted of 20 Grade 11 students who had previously studied ecosystem concepts and demonstrated technological engagement, indicated by daily use of smartphones and regular internet access. These students were selected to complete an open-ended questionnaire designed to capture their learning experiences and preferences in ecosystem-related topics.

Teacher participants included five senior high school biology teachers with experience teaching the ecosystem topic during the last academic year. Their input provided perspectives from experienced practitioners on curriculum alignment and instructional needs.

For the validation stage, three expert validators were purposively selected based on their professional credentials and relevance to the study's focus. These comprised a biology education lecturer with expertise in instructional media development, a senior high school biology teacher experienced in curriculum implementation, and an educational media development specialist with a background in game-based learning.

Data Collection

Data collection began with the distribution of open-ended questionnaires to the selected teachers and students during the **Define** stage. The questionnaire items addressed several focus areas: students' prior learning experiences regarding ecosystems, preferred learning methods (e.g., visual, interactive), availability and frequency of technology use, and perceived difficulties in understanding ecosystem concepts. Responses to yes/no and frequency-based items were analyzed

descriptively, while qualitative responses were coded thematically to identify recurring issues, preferences, and opportunities for instructional media development.

Product Design and Development

The design of *The Riverkeeper* game was informed by the results of the needs analysis conducted during the Define stage. Design decisions included determining the media type (game-based learning), the development platforms (Canva and Wordwall), and the delivery format (a hybrid approach combining digital and field-based activities).

A detailed storyboard was created to guide development, outlining the sequence of game activities, learning content, challenges, and interactive elements. This storyboard served as the blueprint for producing the prototype. At the Develop stage, the initial version of the game underwent expert validation to ensure content accuracy, instructional effectiveness, and usability.

Expert Validation Procedure

The expert validation process utilized a structured validation sheet that assessed three key aspects of the game: (1) clarity and completeness of game guidelines, (2) visual communication and design quality, and (3) functionality of interactive elements. Each criterion was rated on a 4-point Likert scale, where 1 indicated "Not Valid" and 4 indicated "Highly Valid."

Although inter-rater reliability was not calculated due to the small number of validators, the average scores across reviewers were computed to determine the product's overall validity. The categorization of validity levels followed the criteria outlined in Alvionita et al. (2020), as presented in Table 1, which classifies products into "Very Valid," "Fairly Valid," "Less Valid," or "Invalid" categories.

Table 1. Validation Categories

Score range (%)	Validity Categoriy	Conclusion
85.01 ≤ x ≤ 100	Very Valid	Can be used without revision
70.1 ≤ x ≤ 85.00	Fairly Valid	Can be used with minor revisions
50.1 ≤ x ≤ 70.00	Less Valid	Recommended not to be used as it requires a lot of revisions
01.00 ≤ x ≤ 50.00	Invalid	Not usable, requires many revisions

Practicality Testing

Following expert validation, the practicality of the game prototype was tested with the same 20 Grade 11 students who had participated in the Define stage. Students engaged with *The Riverkeeper* game, and their feedback was collected to assess its ease of use, clarity of instructions, and overall suitability for learning ecosystem concepts. This step provided initial insights into the game's usability in a classroom context.

Research Scope and Limitations

This research focused solely on the development, expert validation, and limited practicality testing of *The Riverkeeper* educational game. The later stages of the 4D model, particularly effectiveness evaluation involving pilot testing and learning outcome measurements, were not conducted due to resource and time constraints. These aspects should be addressed in future studies to evaluate the educational impact of the developed game more comprehensively.

Ethical Considerations

This study was conducted in accordance with standard research ethics procedures. Participation was entirely voluntary, and all participants—teachers, students, and expert validators—were selected based on predefined inclusion criteria through purposive sampling. Prior to data collection, participants were informed about the purpose of the study, the nature of their involvement, and the types of data to be collected. Informed consent was obtained from all participants before they completed questionnaires, participated in validation activities, or engaged in the practicality testing of *The Riverkeeper* game.

Confidentiality of participants' information was maintained throughout the research process. Individual responses from questionnaires, validation sheets, and feedback sessions were recorded anonymously and reported in aggregated form to ensure privacy. Participants were assured that their involvement would not affect their academic standing or professional responsibilities. All data collected were used solely for the purposes of this study and stored securely to prevent unauthorized access.

RESULTS AND DISCUSSION

Define Stage

At the Define Stage, the aim was to analyze learning problems and user needs related to ecosystem material through questionnaires distributed to 5 biology teachers and 20 Grade 11 students. Participants were purposively sampled based on their experience in teaching or studying ecosystem topics and their access to digital devices. Based on the findings, according to the Biology teacher, the topic of Ecosystem is one of the most important topics to learn because it is very contextual. The topic of ecosystes is a fundamental topic in science, but there are still many students who have difficulty understanding the concept, causing misconceptions (Putri & Rusyati, 2021). Then, in this case, students as humans are certainly one part of the ecosystem that should understand their role in nature.

Furthermore, based on the results of the questionnaire given, in terms of learning methods, in teaching ecosystem material, many teachers make direct observations in the field to observe the ecosystem in question. One of the important learning activities in ecosystem topics and other biology topics is outdoor learning activities (Jeronen et al., 2016). In addition, lecture and discussion methods are also quite common, but no teacher has integrated these methods in the form of games. According to the teachers, the best learning strategy to teach ecosystem material is the activity that involves students actively solving environmental problems with problem-based learning and direct observation in the field. To complement this, the learning activity that is arranged as much as possible is associated with existing technology. One of the interactive learning media developed and related to technology is known to improve students' analysis and problem-solving skills (Lathifah et al., 2024).

Students' opinions about ecosystem learning were also obtained through an open-ended questionnaire filled out by 20 respondents. The questions given were related to the ecosystem learning they had done. There are seven questions in the questionnaire: 1) Have you learned about ecosystem topic? (yes/no); 2) Ecosystems topic deals with the interactions between living things and their environment. Based on your experience, what methods do your teachers use to teach ecosystems?

(multiple choice – lectures, field observation, game based learning and additional choice type by students); 3) Do you think ecosystem material is important to study? If so, give a brief explanation about it!; 4) In the ecosystem topic, what kind of teaching method do you think is best to apply?; 5) If a game were to be developed in ecosystem learning, what kind of game would you expect in learning? (multiple choice – fully digital, physical game, hybrid game and additional choice type by students); 7) Can you briefly describe what kind of game was chosen in question number 6? (open ended question, students give the explanation about the game). Table 2 show the summary of students' data obtained from the questionnaire.

Table 2. Student Data Summary

Item	Response (%)
Previous learning through lectures	83.3
Previous learning through field observation and other method	17.7
Students view ecosystem topic as an important topic	100
Students prefer hybrid (digital + physical) games	53.3
Students prefer fully digital games	23.3
Students prefer physical Games only	23.3

All students consider that ecosystem material is important to learn. The reason for this is that students can understand the environment in which they live and get to know the interdependent relationship between living things and their environment, so that they have more awareness to protect the environment. One of the statements about this importance is "*Yes, ecosystems are important to study because we live within them. By understanding ecosystems, we learn how living things and their environment interact, how the food chain works, and how humans can maintain environmental balance.*" Students think that the best way to learn the topic of ecosystems is through practice and direct observation in the field, but in reality, there are still many students who learn only the theory in the classroom. Field studies, or better known as field trips, have many advantages in learning. Field trips help develop social awareness and help students get a deeper understanding of what they are learning in the classroom, in this case, improving students' academic performance in the classroom (Timothy & Apata, 2014).

Students also expect learning that is not boring, so if there is a theory delivered by the teacher, media is needed that supports it visually so that students better understand the material being taught. Discussing games in the topic of ecosystems, 53% of students need a game that is a combination of digital and physical games, 23.3% of them choose fully digital games, and another 23.3% choose physical games only. Each respondent gave a description of what kind of game they meant in the questionnaire given. Broadly speaking, respondents answered games such as a *treasure hunt.* In this game scheme, students can explore an ecosystem while finding out about the ecosystem , and there are puzzles to be solved in it; then the winning group will get a *reward* from the game. These are the example of students explanation about hybrid (digital + physical game): "*For the game, perhaps a treasure hunt could be created with an ecosystem theme, where participants must search for clues in their surroundings, such as the school environment, related to the food chain, interactions between living things, or ecosystem balance. This could also be combined with digital tools to keep*

learning up-to-date with technological developments, such as using a website that provides gameplay instructions, additional information, and other resources related to the game.", and "*The game uses an application to provide clues that must be found directly in the surrounding environment*".

In addition to the views of teachers and students, an analysis of the current curriculum was also carried out as the basis for developing the media. For now, high school biology subjects in Phase E in Indonesia have been merged with chemistry and physics subjects into Natural Science (IPA). Based on the Decree of the Head of BSKAP and the Ministry of Education and Culture Number 032/H/KR/2024, Class X, which is included in Phase E in the Merdeka Curriculum, the science learning outcomes, namely: "At the end of Phase E, students can understand measurement systems, alternative energy, ecosystems, biotechnology, biodiversity, atomic structure, chemical reactions, basic laws of chemistry, and climate change so that they are responsive and can play an active role in solving problems on local and global issues". Based on the analysis, the author will develop a game that is expected to be an alternative for ecosystem learning and integrates the use of technology and direct observation in the field so that the concepts received by students are more complete. Besides, research has found that direct observation in the field represents essential elements of experiential learning. When intentionally designed with clear objectives, they can foster the development of higher-order thinking skills such as problem solving and critical thinking skill (Foo & Foo, 2022; Saefudin et al., 2022).

Design Stage

This stage aims to produce a form of presentation of the product or media developed. Based on the results of the *define* stage, the game format will integrate the use of digital technology and physical activities in the field. Students need electronic devices such as a smartphone or a laptop connected to internet facilities to be able to access this game. In the first meeting, students played the game fully digitally, and in the second meeting, students played the game hybridly, exploring the Citarum river ecosystem while doing the activities instructed in the game digitally. In the third meeting, students again accessed the game in the digital classroom to initiate ideas that could become solutions to ecosystem problems.

Some of the media games that inspired the development of this media are *Betty's Brain* (Tan et al, 2005), *Acep the Explorer* (Pratiwi et al, 2022), *Food Chain* (Unyapoti et al, 2024) and game activities in ecosystem learning which consists of four levels, namely 1) *The Conquest*, (2) *Eco-Dama*, 3) *Eco-challenge* and 4) *Eco-warrior* (Lasala, 2023). After determining the format of the game, a storyboard was prepared as the initial design of the game to be developed. *The Riverkeeper* game media developed consists of three main levels. Learning is conducted in groups.

Level 1: The Guardian, using the Full online mode, is accessed using a smartphone and an internet connection. Students access four main icons: River, Factory, School, and Government Building. In the river icon, there is a visualization of the natural scenery of the river with flora and fauna. Learning material contains biotic & abiotic components, the role of organisms in the ecosystem, and interactions in the ecosystem. At the end of the icon menu, there is a mini game in the form of a maze chase on the Wordwall site. The next icon, the factory icon, has a visualization in the form of industrial buildings on the riverbank. The learning material contains the role

of the industrial sector in protecting rivers and sustainable development, then at the end of this icon material is a mini airplane game on the Wordwall site. The third icon is a school building. This material discusses the role of educational institutions in protecting rivers, concrete actions to conserve rivers, and ends with a quiz game show on the Wordwall site. And the last icon in level 1 is the government building. This section discusses related to watershed policies, the role of government, and society in protecting the environment. Level 1 is carried out in 2 x 40 minutes. The winner of level 1 was taken from the group of students who had the highest score from the mini game.

In level 2: The Explorer, the game mode is *hybrid*. In this case, students explored the river area directly by executing the commands on the digital platform (Canva). As in level 1, in level 2, there are also four icons to be explored, and each of them is connected to a worksheet in *Google Docs*. The icons are a universal pH indicator paper, a community house, a visualization of an officer, and also rocks. Activities on the pH indicator paper icon are analyzing the pH of river water, observing the physical condition of river water, and recording data into the LKPD. On the icon of a community house, students are directed to conduct interviews with residents found around the river. Similar to the icon of a citizen's house, on the icon of an officer, students are asked to interview the oxbow officer on duty in the river area, and the last icon of the rock icon has a command to observe the various components of the river ecosystem found. The time allocation required in level 2 activities is 3 lesson hours (3 x 40 minutes). After completing each icon, students earn stars as a sign that their group has completed the mission. The group of students who obtained four stars first was determined as the winner of level 2.

Table 3. Experiential Learning Phase in The Riverkeeper Game Activity

Phase	Explanation
Concrete experience	Students get a concrete experience by visiting the Citarum River in Level 2
Reflective observation	Students interviewing people around the area
Abstract conceptualization	Students do the discussion in group to fill the worksheet that given to them and strengthen the concept about river ecosystem (s.a the components, the food chain, e.t.c)
Active experimentation	Students reflecting and making ideas to keep the River ecosystem balance

The third level was the last level implemented in the 3rd meeting. In this level, there are not as many icons or commands as in levels 1 and 2. In this Savior level, each group of students is given a role, either as a business person, an official in a government agency or part of an educational institution. Each group of students was directed to initiate an idea to protect the river according to the role they received. Each idea is written by the group in a Google Doc document, so that each student can read the ideas of each group. With this, it is hoped that students can understand that to protect the river, not only one sector plays a role, but all existing sectors, ranging from government agencies, educational institutions, business people, and the community, must work together to become unified. In designing the whole game, the author refers

to the concept of experiential learning by Kolb (1984) which consists of 4 phases. The explanation for every phase is shown in Table 3. By designing the activity that fits to experiential learning phase, the author wish it could lead to a deeper understanding and more meaningful for students. Not only meaningful but also joyful and stimulate students to be mindful about their environment.

Development Stage

At this stage, game development is carried out based on the initial design that has been made using the Canva application, which is integrated with Wordwall and Google Docs. Those application were chosen because it need no special expertise to code or making the game, easy to access and do not require much cost in development process. In terms of the word 'development' refers to an activity to produce a new tool or method, where the activity will continue to be evaluated and improved to improve quality. Development can be interpreted as a plan to develop something that already exists to improve more advanced quality (Ediyani et al, 2020). The game developed was inspired by various existing educational games, named The Riverkeeper game. The novelty of The Riverkeeper game is that the game consists of online and offline modes, consisting of three levels for a total of three meetings. The main application used is the Canva application, which has features to link various online sites such as Wordwall and Google Docs.

Table 4. Description of Apps/Sites used in the Riverkeeper Game

Apps/Sites	Features Used
Canva	-Elements (Insert picture, video & sound)
	-Animation
	-Hyperlink
	-Insert text
Wordwall	-My Activities
	Maze chase game, airplane game, gameshow quiz.
	-My result
	View student work
Google Docs	-Sharing documents
	-Insert text
	-Insert picture

Canva is one of the most popular platforms in education. Various activities such as making presentations, designing posters, and making videos (Ikhlas et al., 2023). In addition, there are also several educational games based on Canva applications, such as '*Unlock Your Potential*', an Arabic language educational game (Tania & Ammar, 2025), and the implementation of Team Games Tournament based on Canva and Kahoot! applications in arithmetic learning (Siahaan & Nasution, 2022). However, there is no integration of the Canva platform with Wordwall and Google Docs sites, especially in Biology subjects in Indonesia. Canva was chosen because of its relatively easy application, then it has many conveniences such as templates and various interesting elements and features (Saputra et al., 2022). Another advantage is that the Canva application is available for free, so it can be accessed by many people. An explanation of the features used to develop The Riverkeeper game is available in Table 4.

Canva used as the main application contains various materials learned related to ecosystems and their integration with social life on how to maintain river ecosystems from the point of view of businesses, government agencies, and educational institutions. In th e other hand, Wordwall used as on online game site is linked to the main Canva application that students open when they have finished studying one of the game sessions.The game options used in this game are the quiz, maze chase, and airplane modes. Then the last one is Google Doc. Google Doc is the online document site that is linked to the main Canva app used in level 2 and level 3. This contains worksheets that must be done by students in every level.

To access this game, students need to use an electronic device that is also connected to the internet. Users can use either laptops or smartphones by first downloading the Canva and Google Docs applications on the electronic device. The use of electronic devices such as laptops has provided better results in terms of student engagement with videos, collaborative behavior and their satisfaction with the device (Albo et al., 2018).

Figure 2. The Icons in Level 1, The Guardian

Figure 3. Example of learning materials page

Figure 4. Level 3 command (The Savior)

As explained in the previous section, in The Riverkeeper game, there are three levels based on the storyboard that has been made at the design stage. Every icon in each level can be seen in Figure 2, Figure 3, Figure 4 and detailed in Table 5. The graphic presentation style of the game is also part of the educational game development process. The effectiveness of the graphical presentation style in

educational games is also beneficial for students in their learning process (Gee & Dolah, 2016).

Table 5. Figure Caption

Icons	Definition
Number level	Level number, positioned at the top left corner
Icon in Level 1	An example of a clickable icon to access the learning materials and quizzes in the game
Riverhero	Riverhero, the icon that appears at the beginning of each level and provides narrative story and instructions.
Klik setiap ikon yang berkedip dan selesaikan misinya! *Level instruction*	The example of Instruction in every level
Level up button	Clickable icon to go to another level after finishing one level
Game/Quiz button	Clickable icon to go to game or quizz page
Back button	Clickable icon to go to previous

Expert Validation Results

The game media was validated by 3 validators who were biology education lecturers, media experts, and biology teachers. The validation sheet provided contains three main assessment aspects, namely 1) game guidelines; 2) visual communication and design aspects, and 3) functionality aspects. All the validators were purposively

selected based on their speciality expertise. The full rubric of the validation instrument is attached in this article as supplementary file.

Based on validator A, the overall score obtained was 87,5. Validator B gave a score of 93, and the validation score from the third validator was 86. From the three validation scores obtained, the average score is 88, so that The Riverkeeper game media can be categorized as very valid. However, there are some improvement notes form the validators to make the game even better. These notes include the addition of a 'back' button on several parts of the page, and if possible for further development of quizzes and games at each level and worksheets integrated in one platform for easier access. The details of the assessment scores from the validators can be seen in Table 6.

Table 6. Validation Score of Each Aspect

Validator	Game Guide	Visual Communication and Design	Functionality
A	93.75	91.7	75
B	93.75	88.8	100
C	87.5	88.8	80
Average Score	**91.6**	**89.7**	**85**

Of the three aspects, the highest score was obtained in the assessment aspect related to the game guide. This shows that there are guidelines that are quite clear and easy to understand for game media development. As for the scores of visual communication and design aspects, the scores given by each validator were not far apart from each other. A game guidelines is needed in every game based activities in the classroom, it must be written clearly, easy to follow, and suitable with students' age range so that could lead the increase of expected benefits of game-based learning activities (Alfadhli & Alsumait, 2015).

In the assessment of communication, visual and design aspects, information was obtained that the media created used language and instructions that were easy to understand, the size and color of the text were contrasting, the images and icons could generate student interest, the images and videos were following the material presented, the game made it easier for students to understand the material and made students more active. However, the last aspect, namely the functionality aspect, obtained the lowest average score but was still in the good category. Based on the validation results, what caused this aspect to have the lowest score was that there were obstacles found on the device that felt the loading time was quite long, the internet connection at the time of testing was less supportive, and there were links that were error, so revisions were needed.

The Riverkeeper game was designed by applying Mayer and Moreno (1998) multimedia principles to minimize split-attention and cognitive overload, ensuring integrated visuals and text for clear learning pathways. Expert validation by media and pedagogical specialists assessed whether these principles were effectively implemented in guiding student interaction with the Games.

Practicality Testing Results

A practicality test was conducted to 20 students after game completion. Students completed a Likert-scale questionnaire (1=Strongly Disagree to 5=Strongly Agree) assessing four criteria as presented in Table 7.

Table 7. Criteria of Students' Practicality Test Questionnaire

Criteria	Average Score (Max 5)
Students' point of view about The Riverkeeper game	4.02
Students' point of view of learning using The Riverkeeper game	4.04
Game attractiveness	3.98
Suitability to learning outcomes	3.96
Average	**4.0**

In the first criteria (the score is 4.02 of 5), students' point of view about The Riverkeeper games are the images and videos in the game are relevant to the material presented, the ecosystem material and the language/instructions in the game are easy to understand. For the second criteria (score 4.04 of 5), students' point of view of learning using The Riverkeeper game are most student feel more engaged when learning with The Riverkeeper, find it easier to connect various ecosystem concepts after playing the game, and helps them improve teamwork. Third criteria are about game attractiveness that gain 3.96 score out of 5. Students think The Riverkeeper is an engaging learning tool, the Riverkeeper game helps increase their motivation to learn, and the game makes learning more enjoyable and less boring.

The last criteria are suitability to learning outcomes that gain score 3.96 out of 5. The Riverkeeper game made students more environmentally conscious, students also think that the media used in The Riverkeeper game aligns with the learning objectives, and the learning method, combined with field studies, aligns with the learning objectives for the ecosystem topic. Students reported high satisfaction, emphasizing enjoyment, ease of understanding, and increased ecological awareness. Serious games, gamification and game-based learning in general, can make Biology lesson more fun, enjoyable but still meaningful (Kinchin, 2018; Situmorang et al., 2024). Practicality testing suggested positive student acceptance, indicating the game's pedagogical potential. However, full-scale implementation trials and impact analysis on student learning outcomes remain as critical next steps to validate educational effectiveness.

Challenges in Development

In developing 'The Riverkeeper' prototype, there are some challenges that are faced from define stage until develop stage. First, in the define stages, the questionnaire was given to the teachers and students on line via Google form because this research was held during exam. It would be better if interview data were obtained. Another challenge was found when developing the game in Canva and Wordwall. The templates are limited if we use free account, so we must upgrade the account from basic to pro, in order to access the whole templates and menu.

CONCLUSION

This study developed and validated the Riverkeeper game as an innovative hybrid learning media to teach ecosystem topics to high school students. Grounded in constructivist and experiential learning theories, the game integrates Canva, Wordwall, and Google Docs platforms, combining digital exploration with real-world field activities. Through the 4D development model, the game was systematically

designed, involving input from biology teachers and students to ensure contextual relevance and user-centered design.

Validation results from experts categorized the game as very valid, particularly in its instructional clarity and engaging visual design. Practicality tests also showed high student satisfaction and perceived learning relevance. Despite minor technical limitations, the Riverkeeper game demonstrates strong potential as an interactive educational tool to address conceptual difficulties in ecosystem learning and foster environmental awareness. Further implementation trials are recommended to assess its impact on student learning outcomes.

RECOMMENDATIONS

There are some notes for future improvement. Of the three aspects of assessment, the functionality aspect obtained the lowest score because there were obstacles found on the device that the loading time was quite long, the internet connection at the time of testing was less supportive, and there were links that were error, so revisions were needed. Development game with the same concept in other topics also can be made. For further development and research recommendations, similar game media can be made with more professional software (e.g unity), and all quizzes and worksheets are sufficiently integrated into one main platform.

Conflict of interests
The authors declare no conflict of interest.

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SUPPLEMENTARY FILE

The Riverkeeper Game Validation Rubric

Part 1: Game Guide Aspect

Statement	1 (Very Poor)	2 (Poor)	3 (Good)	4 (Excellent)
1. There is a guide file to operate the game	No guide file available	Guide file incomplete	Guide file mostly complete	Complete guide file available
2. The game guide is constructed systematically	No clear structure	Structure unclear	Mostly systematic structure	Clear and systematic structure
3. The game guide shows complete steps	Many steps missing	Some steps missing	Most steps included	All steps complete and clear
4. Sentences in the game guide are easy to understand	Very difficult to understand	Somewhat difficult to understand	Mostly clear	Very clear and easy to understand

Part 2: Communication and Visual Design Aspect

Statement	1 (Very Poor)	2 (Poor)	3 (Good)	4 (Excellent)
1. Language instruction is clear	Very unclear	Somewhat unclear	Mostly clear	Very clear
2. Story flow is easy to understand	Very confusing	Somewhat unclear	Mostly clear	Very clear and coherent
3. Text size and font style are proportional to the picture	Not proportional	Poorly balanced	Mostly proportional	Fully proportional and balanced
4. Font color contrasts with background	Very poor contrast	Poor contrast	Good contrast	Excellent, highly readable contrast
5. Font style is easy to read	Very hard to read	Somewhat hard to read	Mostly easy to read	Very easy to read
6. Pictures and icons make students interested	Not interesting	Less interesting	Moderately interesting	Very interesting
7. Pictures and videos in the game	Not appropriate	Partially appropriate	Mostly appropriate	Fully appropriate

Statement	1 (Very Poor)	2 (Poor)	3 (Good)	4 (Excellent)
are appropriate with the topic				
8. Game helps students understand the topic	Not helpful	Slightly helpful	Mostly helpful	Very helpful
9. Game makes students more active in learning	No active participation	Limited active participation	Mostly active participation	Very active participation

Part 3: Functionality Aspect

Statement	1 (Very Poor)	2 (Poor)	3 (Good)	4 (Excellent)
1. Game is compatible with all types of laptops or smartphones	Not compatible	Limited compatibility	Mostly compatible	Fully compatible
2. Game is easy to access (includes active link)	Very difficult to access	Somewhat difficult to access	Mostly easy to access	Very easy to access
3. All buttons in the game work	Many buttons do not work	Some buttons do not work	Most buttons work	All buttons work
4. Size of buttons is proportional to screen and easy to click	Very hard to click	Somewhat hard to click	Mostly easy to click	Very easy to click
5. Loading time is minimal	Very slow loading	Slow loading	Acceptable loading speed	Very fast loading