ISEJ Indonesian Science Education Journal

ISSN Online: 2716-3350
https://siducat.org/index.php/isej/
Published by Yayasan Darussalam Bengkulu

OPEN ACCESS ARTICLE

Rabbit Population Dynamics: A Game-Based Learning Media for Teaching Population Dynamics in Biology

Purwati Kiswarini Suprapto[1], Liah Badriah[2*], Dani Ramdani[3]
Department of Biology Education, Universitas Siliwangi, Tasikmalaya, Indonesia[1,2,3]
E-mail Corresponding: liahbadriah@unsil.ac.id

Received: March 9, 2027	Revised: May 10, 2026	Accepted: May 27, 2026

Abstract
The integration of Information and Communication Technology (ICT) has encouraged the development of more interactive, contextual, and student-centered biology learning media. However, population dynamics remains a challenging topic for students because ecological interactions, such as population growth, predator–prey relationships, environmental carrying capacity, and resource availability, are abstract and cannot always be observed directly in classroom settings. This study aimed to design and evaluate the feasibility of Rabbit Population Dynamics (RPD), a game-based learning medium developed to support students' understanding of population dynamics. This research and development study employed the ADDIE model, consisting of analysis, design, development, implementation, and evaluation, integrated with Merrill's principles of instruction to strengthen the pedagogical structure of the media. Product feasibility was examined through media expert validation, content expert validation, and a small-group trial involving 13 university students who had studied population dynamics. The results showed media validation of 87.90% in the highly feasible category, content validation of 93.90% in the highly feasible category, and a small-group trial score of 87.27% in the highly feasible category. These findings indicate that RPD is highly feasible as an interactive learning medium for the population dynamics subtopic. Further classroom implementation with high-school students is recommended to examine its effect on conceptual understanding, learning engagement, and problem-solving skills in biology learning.

Keywords: ADDIE, Ecology, Game-Based Learning, Population Dynamics, Rabbit Population Dynamics

INTRODUCTION

Entering the 21st century, the integration of technology in the learning process has become an indispensable necessity. Technology plays a crucial role in developing a learning process that is more interactive, effective, and relevant to the demands of the times. At the high school level, particularly in Biology classes, the integration of technology can provide a more immersive and engaging learning experience for students (Alfiansyah 2024). One increasingly popular form of technology integration is the use of game-based learning in education. Game-based learning not only motivates students to learn but also helps them develop essential 21st-century skills, such as critical thinking, creativity, collaboration, and communication (Robberts and Van Ryneveld 2022). Research conducted by Hartt, Hosseini, and Mostafapour (2020) demonstrates that game-based learning can enhance student engagement and facilitate more effective learning through enjoyable and challenging activities.

The development of 21st-century skills is essential, especially in addressing global challenges and the increasingly competitive job market. These skills, which encompass critical thinking, problem-solving, teamwork, and digital literacy, are considered essential competencies for young people to succeed in the future. In various developed countries, such as Finland and South Korea, the integration of technology into education has been effectively implemented to enhance learning quality and student outcomes. For example, research in South Korea found that

using educational games in science learning not only boosted student motivation and engagement but also significantly improved understanding of complex concepts (Kang 2019). In Finland, game-based learning has been widely applied in schools with positive outcomes in developing students' cognitive and non-cognitive skills (Hui and Mahmud 2023). This demonstrates that the integration of technology and the implementation of game-based learning in education are not only relevant but also effective in enhancing 21st-century skills, especially in Biology education

The study of Biology, particularly in the area of ecology with a focus on population dynamics, is one of the topics frequently perceived as challenging by students. The complexity of concepts related to population dynamics such as population growth, environmental carrying capacity, and interspecies interactions often presents comprehension difficulties. A primary reason for this difficulty lies in the limited learning environments in schools, which struggle to provide concrete and direct examples of these phenomena (Lasaiba 2023). In most school settings, population dynamics phenomena cannot be directly observed due to constraints in time, space, and resources. This situation makes the learning process more abstract and theoretical, thereby hindering students' ability to fully understand and internalize these concepts (Alina and Wathona 2019).

A study conducted by Jansen, Scherer, dan Schroeders (2015) demonstrates that many students struggle to understand ecological concepts, particularly when the material cannot be illustrated with real-life examples from their surroundings. Another study by Rahmawati et al. (2022) also reveals that students' understanding of population dynamics significantly improves when they engage in learning activities that provide simulations or visual representations of the phenomena. This indicates that the limitations of the real environment in providing concrete examples can be addressed through the use of interactive and contextual learning media

By using game-based learning, the difficulty in learning population dynamics can be overcome through simulation and visualization that provides a more concrete and real learning experience for students (Kim, Sin, and Yoo-Lee 2014). This approach allows students to interact directly with population simulation models, manipulate key variables, and observe the impact of these changes in an ecosystem (Dickes et al. 2019). Through this interaction, students can more easily understand difficult and abstract concepts, because they can see firsthand how populations grow and interact in a controlled and guided environment. Therefore, game-based learning is not only an innovative learning tool, but also an effective solution to overcome the limitations of learning Biology in the classroom (Asniza et al. 2021).

Although conventional learning methods are still widely used in schools, research shows that this approach has several significant weaknesses, especially in learning complex concepts such as population dynamics in Biology. One of the main weaknesses of traditional methods is the lack of student involvement in the learning process. This method often focuses on one-way lectures and providing theoretical material without giving students the opportunity to actively interact with the material being studied (Thaariq, Nurdiyanto, & Sulfa 2023). This causes students to tend to be passive and less involved in learning, thus negatively impacting understanding and retention of the material.

In addition, conventional learning methods often fail to reflect students' true abilities in understanding and applying the concepts they learn. In a study by (Goodyear and Carvalho 2019), it was found that many students find it difficult to relate the theories taught in class to real situations they face in their daily environment. This is especially true for abstract concepts in Biology, such as population dynamics, where students cannot see or experience the phenomena being discussed directly. This weakness hinders students' ability to think critically and creatively, as well as to develop problem-solving skills needed in real life and the workplace (Matthee and Turpin 2019).

Considering the various weaknesses in these conventional learning methods, it is clear that there is an urgent need to develop learning methods that are more effective and in line with the needs of today's students. Game-based learning, as one alternative, offers a potential solution to overcome these weaknesses by creating a more interactive and enjoyable learning environment, which can increase student engagement and help them understand difficult concepts better (Munandar 2023).

Although various studies have shown the effectiveness of game-based learning in improving students' understanding of complex concepts and engagement, there is still a research gap in the application of this method to Biology learning, especially on the concept of population dynamics in high schools. Previous studies, such as those conducted by (Lin, Liang, and Tsai 2015), have focused more on developing games for basic concepts in Biology, but not many have targeted specific concepts such as population dynamics that require an in-depth understanding of interactions between species and environmental factors. In addition, although a study by (Hartt et al. 2020) showed that game-based learning can improve learning outcomes and student engagement in general, there is still no research that specifically evaluates the effectiveness of educational games in facilitating students' understanding of more abstract and dynamic concepts in ecology, such as population dynamics. Meanwhile, local studies such as those conducted by (Widiana and Jampel 2016) indicate that conventional teaching methods still dominate Biology learning in Indonesia, which indicates the need for further research to develop and test the effectiveness of alternative learning methods such as game-based learning in the Indonesian educational context.

Therefore, this study aims to design and develop game-based educational learning focused on Biology education, particularly the concept of population dynamics, as an effort to enhance the quality of learning and equip students with the skills needed to compete in the global arena. This research is expected to make a significant contribution to the development of innovative and effective learning methods and to support efforts to improve the quality of education in Indonesia. However, most available studies remain oriented toward general engagement or conceptual understanding, whereas design-oriented evidence for a locally developed game that represents predator-prey and resource interactions in the population dynamics subtopic is still limited.

Therefore, this study aimed to design and develop Rabbit Population Dynamics (RPD), a game-based learning medium for Biology learning on the concept of population dynamics. The study was intended to evaluate the feasibility of RPD through media validation, content validation, and a small-group trial, while also demonstrating how game-based simulation can support students in visualizing ecological interactions that are difficult to observe directly in the classroom. This research is expected to contribute to the development of innovative, interactive, and contextually relevant Biology learning media in Indonesia.

METHODS

Research Subjects and Location

This study was conducted in Tasikmalaya City, West Java, with first-year senior high-school students positioned as the intended users of the developed learning media. The target users were selected because population dynamics in ecology is often difficult to visualize when it is presented only verbally or through static classroom resources. In the validation stage, media and content experts evaluated the product, while a small-group trial involved 13 university students who had previously studied population dynamics in ecology courses. The small-group trial was treated as preliminary usability and clarity testing rather than as a full classroom-effectiveness test with high-school students.

Research Design

This study used the ADDIE (Analysis, Design, Development, Implementation, Evaluation) development method to design and develop the educational game "Rabbit Population Dynamics"

which was intended to support Biology learning, especially the concept of population dynamics. The ADDIE method was chosen because it provides a systematic and structured framework for the development of technology-based learning materials, ensuring that each stage is checked and improved before final implementation (Setyosari 2020). This approach also allows for continuous evaluation and continuous improvement, which are important in ensuring the effectiveness of the game in an educational context

In practice, the ADDIE development model for designing the RPD application is integrated with Merrill's principles of instruction. This model consists of task-centered, integration, activation, application, and demonstration (Merrill 2007).

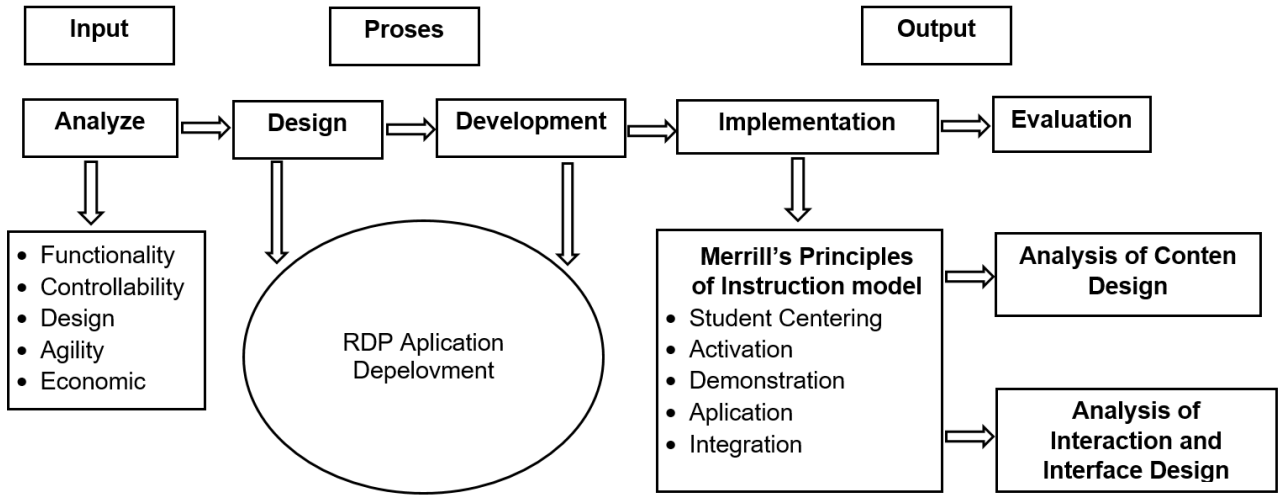

Figure 1. Application of Merrill's instructional principles model

The instruments used in this study consisted of a media validation sheet, a material-content validation sheet, and a small-group user-response questionnaire. The media validation sheet assessed technical appearance, content and purpose, instructional quality, display quality, ease of use, accessibility, and media practicality. The content validation sheet assessed population knowledge in ecosystems, strategies for maintaining population balance, and factors affecting population change. The small-group questionnaire assessed media presentation, clarity of information, use of the application program, and perceived effectiveness of the media for learning. The collected scores were converted into percentages and interpreted using feasibility categories, while qualitative inputs from validators and users were used to refine the product and interpret the findings.

RESULT AND DISCUSSION

The development process followed the ADDIE stages to produce a learning medium that could support Biology learning more effectively and efficiently. The analysis stage involved identifying learning needs, validating instruments with media and material experts, and considering the suitability of the RPD game for Grade X students. The design stage included preparing the storyboard, navigation structure, and learning flow. The development stage involved building a web-based application and preparing content aligned with the population dynamics subtopic. The implementation stage involved expert validation and a small-group trial to determine whether the application functioned according to its instructional objectives.

Rabbit Population Dynamic Learning Media Product

Rabbit Population Dynamics is a game-based learning medium that invites players to manage ecosystem balance. The player is required to maintain the population of rabbits, tigers, and grass

so that the simulated ecosystem remains stable. The game is designed to help students understand interactions among organisms and the importance of maintaining balance so that each species can survive. In the simulation, players also manage environmental resources such as rainfall, which supports grass growth as food for rabbits, while rabbits function as prey for tigers. By adjusting these environmental factors, students can observe how changes in one component affect the population of other components. Thus, Rabbit Population Dynamics provides a direct simulation experience of population dynamics and ecological principles, allowing students to learn biological concepts in a more practical and interactive way.

Figure 2. Rabbit Population Dynamics Front View

Based on the appearance of the RPD, there is some information available in the menu displayed on the web-based application.

1. Information in Main Menu

The main menu in this simulation provides a comprehensive overview of the ecosystem being modelled. It presents information about important components such as rainfall, grass, rabbits, and leopards. Rainfall plays an important role in grass growth, grass functions as the main food source for rabbits, and rabbits become part of the food chain as prey for leopards. By understanding this information, learners can more easily follow the population dynamics represented in the simulation.

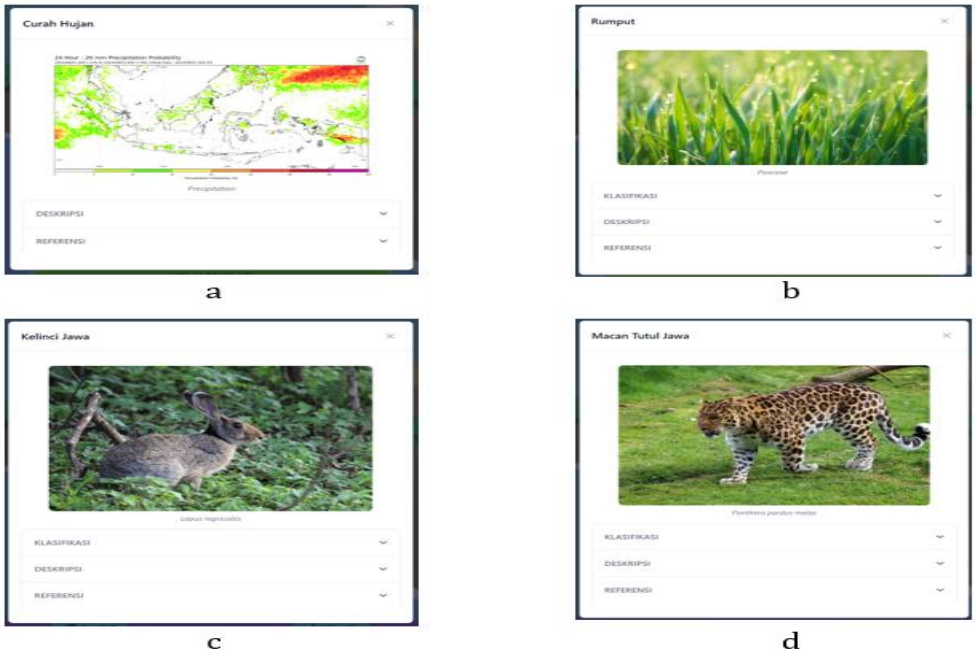

Figure 3. Main Information on the RPD Menu

2. Application Instructions

The application instructions provide step-by-step guidance for using the available features. Learners can access the information needed to operate the educational game, and the guide is presented through text, images, and video-based explanations to accommodate different learning preferences.

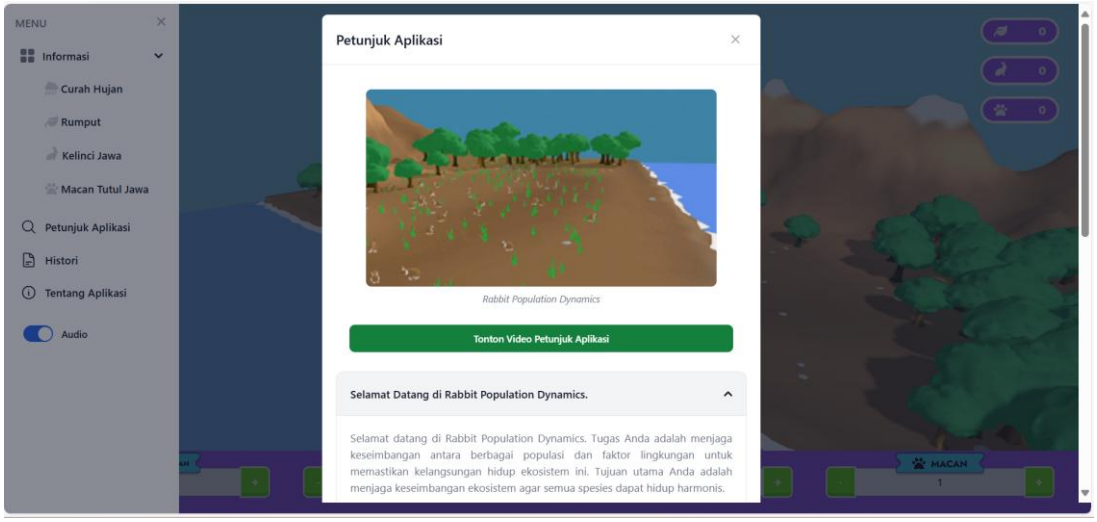

Figure 4. RPD Game Application Instructions

3. History

The "History" icon on the RPD functions to save and display notes or track records of previously conducted simulations. With this feature, students as users can review the simulation results that have been saved, such as the date and time of the simulation, as well as other important data such as the number of grass, rabbit, and leopard populations at the end of the simulation. This information is very useful for analyzing population development over time, comparing different simulation results, or identifying certain patterns in ecosystem dynamics. In addition, the history feature can also be used as a reference for conducting further experiments or simulations with different parameters.

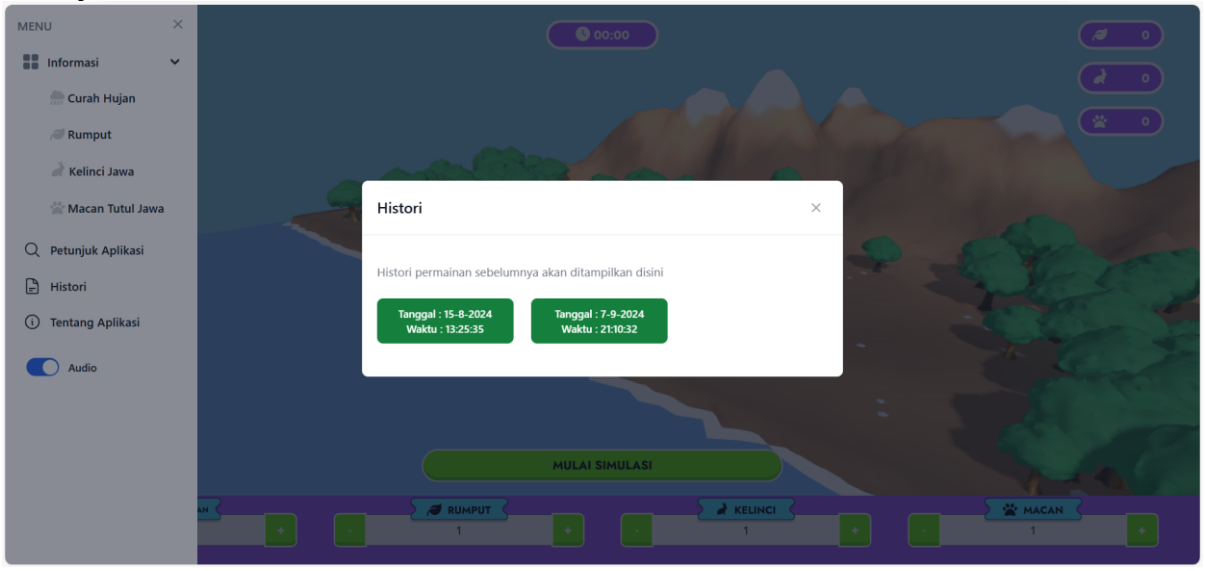

Figure 5. History of RPD Application Usage

Learning Model for the Application of Media in the Classroom

The learning model using the educational game media Rabbit Population Dynamics (RPD) can be effectively integrated with the Problem-Based Learning (PBL) model. RPD facilitates interactive

learning in understanding population dynamics through simulations of diverse ecosystem scenarios. This integration aligns well with the PBL approach, where students solve real-world problems through critical reasoning and collaboration (Haruehansawasin and Kiattikomol 2018). For instance, after receiving a case study on changes in rabbit populations, students can use RPD to simulate scenarios and analyze the results, thereby connecting theory to real-world applications. According to Çetin (2018), the integration of simulation in PBL enhances students' conceptual understanding and critical thinking skills. RPD also allows for differentiated learning, accommodating various student learning styles, including visual, kinesthetic, and analytical. This makes the approach effective in addressing gaps in understanding complex concepts (Simanjuntak et al. 2021). Additionally, this integration develops collaboration, communication, and problem-solving skills, enabling students to learn to work in teams and test solutions through simulations. Previous research conducted by Gunawan et al. (2019) supports the notion that interactive media in PBL enhances students' analytical abilities and decision-making skills. Thus, the integration of RPD and PBL not only enriches the classroom learning process but also prepares students to face challenges in the real world

Figure 6. RPD simulation results presented as a graph

The results of the RPD game simulation can be seen in Figure 6, which presents the observed variables: grass, rabbits, tigers, rainfall, and space. Students can use the graph to think critically about relationships among variables, such as whether changes in grass are related to rainfall or available space and why the rabbit population increases or decreases over time. Through these variables, students are encouraged to explain ecological phenomena and connect simulation results with real-life ecosystem problems.

Product Feasibility as Learning Media

The product feasibility as a learning medium was evaluated using a questionnaire completed by a media expert, namely a lecturer in information technology with expertise in developing game-based applications. This validation assessed the extent to which the product was suitable for use as learning media. The expert input and assessment became the basis for evaluating the quality of the developed media. The results of this validation are summarized in Table 1, which includes several assessed aspects, such as interface design, functionality, interactivity, ease of use, accessibility, and practicality.

Table 1. Results of Product Development Validation as Learning Media

No	Indicator	Percentage	Criteria
1.	Technical appearance of media	90 %	Highly feasible/valid

2.	Quality of content and purpose	100 %	Highly feasible/valid
3.	Instructional quality	75 %	Feasible/valid
4.	Quality of display	83.50 %	Highly feasible/valid
5.	Ease of use	97 %	Highly feasible/valid
6.	Accessibility	70 %	Feasible/valid
7.	Practicality of media	100 %	Highly feasible/valid
	Average Percentage	87.90 %	Highly feasible/valid

The product validation results show that the developed learning media has a very high level of feasibility, with an average percentage reaching 87.9%. This indicates that the product has met most of the criteria expected from an effective learning media. Aspects such as technical appearance, content quality, and ease of use received very good scores, indicating that the product has been well designed and takes into account user needs.

This finding is in line with previous studies that emphasize the importance of intuitive design and relevant content in increasing the effectiveness of learning media (Nicolaou, Matsiola & Kalliris 2019). In addition, the validation results also support the idea that the use of interactive technology can improve student learning motivation and learning outcomes (Sahronih, Purwanto & Sumantri 2019). It is important to remember that the success of a learning medium is not only determined by technical aspects, but also by contextual factors such as student characteristics, learning objectives, and learning environments (Sailer, Schultz-Pernice & Fischer 2021). Therefore, it is necessary to adapt and modify the product according to the specific needs of each learning context.

However, the accessibility indicator obtained the lowest score, namely 70%, which shows that this aspect still requires further improvement. This score indicates that although the RPD media is feasible, its use may still be limited by several access-related factors, such as device compatibility, internet availability, screen readability, navigation clarity, and students' digital familiarity. Because the application is web-based and designed to run on computer devices, students with limited access to stable internet connections or adequate devices may experience difficulties in using the media optimally. Therefore, future product improvement should prioritize accessibility by optimizing the application for different devices and browsers, improving font size and colour contrast, simplifying navigation instructions, reducing loading time, and preparing low-bandwidth or offline alternatives. These improvements are necessary to ensure that the RPD media is not only valid and interactive but also more inclusive and usable in diverse school contexts.

Product Feasibility Based on Material Content

This learning medium also underwent content validation. The validation was conducted by Biology Education lecturers at Siliwangi University who had expertise in ecology. The assessment focused on the suitability, accuracy, and relevance of the content used in the RPD application for learning population dynamics.

Table 2. Content Validation Results of the Material

No	Indicator	Precentage	Criteria
1	Population Knowledge in Ecosystems	86.70 %	Highly feasible/valid
2	How to Maintain Population	100 %	Highly feasible/valid
3	Factors Affecting Population Change	93.30 %	Highly feasible/valid
	Average Percentage	93.30 %	Highly feasible/valid

Based on the data presented in the table, the average validation result of the media from the material aspect is 93.3%. This figure indicates that the analyzed learning media is highly valid and suitable for enhancing students' conceptual understanding in population dynamics learning for grade X of Senior High School and its equivalents. For further development, it is recommended that the variety of questions within the learning media be increased. This aims to

provide a more diverse and engaging learning experience for students, thereby maximizing the effectiveness of media use in the learning process. The addition of question variety can help stimulate critical thinking and student engagement, making the learning experience more interactive and enjoyable.

These findings align with previous research that emphasizes the importance of content quality in enhancing learning effectiveness (Al-Fraihat et al. 2020). Relevant and accurate content can help students build a better understanding of the concepts being taught and improve information retention. Furthermore, the validation results also support the idea that well-designed learning media can enhance student motivation (Asmianto et al. 2022).

Although the content validation results of the learning materials are very satisfactory, there remains potential to enhance the quality of this learning media. One recommendation provided is to increase the variety of questions within the learning media. A greater variety of questions can help stimulate students' critical thinking and encourage them to apply the knowledge they have acquired in various contexts. This aligns with constructivist views that emphasize the importance of active and meaningful learning (Zajda 2021). Additionally, varying the questions can help maintain students' interest in learning and prevent boredom. Research has shown that variability in tasks and learning activities can enhance student motivation and engagement (Yu, Gao & Wang 2021). Therefore, by increasing the variety of questions, this learning media can become a more effective tool for achieving the desired learning outcomes

Results of the Small Group Trial

This learning medium also underwent content validation. The validation was conducted by Biology Education lecturers at Siliwangi University who had expertise in ecology. The assessment focused on the suitability, accuracy, and relevance of the content used in the RPD application for learning population dynamics.

Table. 3 Result of the Small-Group Trial

No	Indicator	Precentage	Criteria
1	Media Presentation	84.31 %	Highly feasible/valid
2	Clarity of Information	88.25 %	Highly feasible/valid
3	Use of media and application programs	86.26 %	Highly feasible/valid
4	Effectiveness of Media and Learning	90.25 %	Highly feasible/valid
	Average Percentage	87.27 %	Highly feasible/valid

The small-group trial indicated that the learning media achieved an average percentage of 87.27%. This result suggests that the media was considered highly valid and appropriate from the perspective of potential users. Among the four assessed criteria, media and learning effectiveness received the highest percentage, namely 90.25%. This indicates that most users perceived the media as motivating, engaging, easy to use, and helpful for learning population dynamics.

These results indicate that the media is not only feasible but also has potential to support students' motivation and interest in learning. Users highlighted the ease of application installation and the additional information available in the educational game. This positive response suggests that the RPD application can be optimized in broader learning contexts, particularly when it is adjusted to students' needs, learning characteristics, and classroom conditions.

CONCLUSION

This study developed the RPD application as an alternative game-based learning medium for the ecology subtopic of population dynamics in Biology education. The application was designed to help students visualize interactions among organisms that are difficult to observe directly in everyday learning environments. The RPD application was assessed as highly feasible, with an

average media-validation percentage of 87.90%, a content-validation percentage of 93.90%, and a small-group trial result of 87.27%. These results indicate that RPD is suitable for implementation as an interactive learning medium that can create a more enjoyable learning atmosphere and support students' learning experience. However, because the small-group trial involved only 13 university students and was not yet implemented in a full high-school classroom, future studies should test the application with the intended high-school users and examine its effect on conceptual understanding, motivation, and learning outcomes.

ACKNOWLEDGEMENT

The authors express their gratitude for the funding provided by the Institute for Research and Community Service of Siliwangi University through the 2024 Research and Community Service Grant program under the Siliwangi University Superior Research Scheme (project number 161/UN58.06/PM.00.00/2024). The authors also thank all students who agreed to participate in this research.

REFERENCE

Al-Fraihat, D., Joy, M., Masa'deh, R., & Sinclair, J. (2020). Evaluating e-learning systems success: An empirical study. *Computers in Human Behavior, 102*, 67–86. https://doi.org/10.1016/j.chb.2019.08.004

Alfiansyah, A. (2024). Pembelajaran dan implementasi media pembelajaran teknologi layanan jaringan berbasis mobile: Sebuah pendekatan inovatif untuk pendidikan. *Journal Creativity, 2*(1), 121–132. https://doi.org/10.62288/creativity.v2i1.13

Alina, N., & Wathona, A. (2019). Pembelajaran aktif melalui alat permainan edukatif. *Sistim Informasi Manajemen, 2*(2), 29–47.

Asmianto, M. H., Rahmadani, D., Pusawidjayanti, K., & Wahyuningsih, S. (2022). Developing Android-based interactive e-modules on trigonometry to enhance the learning motivation of students. *International Journal of Interactive Mobile Technologies (iJIM), 16*(02), 159–170. https://doi.org/10.3991/ijim.v16i02.27503

Asniza, I. N., Zuraidah, M. O. S., Baharuddin, A. R. M., Zuhair, Z. M., & Nooraıda, Y. (2021). Online game-based learning using Kahoot! to enhance pre-university students' active learning: A students' perception in biology classroom. *Journal of Turkish Science Education, 18*(1), 145–160. https://doi.org/10.36681/tused.2021.57

Çetin, A. (2018). Simulasyon destekli işbirliğine dayalı öğrenme yönteminin fizik başarısına, bilimsel süreç becerilerine, fizik ve akıllı tahta kullanımına yönelik tutumlara etkileri. *Kastamonu Üniversitesi Kastamonu Eğitim Dergisi*, 57–65. https://doi.org/10.24106/kefdergi.375173

Dickes, A. C., Kamarainen, A., Metcalf, S. J., Gün-Yildiz, S., Brennan, K., Grotzer, T., & Dede, C. (2019). Scaffolding ecosystems science practice by blending immersive environments and computational modeling. *British Journal of Educational Technology, 50*(5), 2181–2202. https://doi.org/10.1111/bjet.12806

Goodyear, P., & Carvalho, L. (2019). The analysis of complex learning environments. In *Rethinking pedagogy for a digital age* (3rd ed., pp. 49–65). Routledge. https://doi.org/10.4324/9781351252805-4

Gunawan, G., Harjono, A., Heryati, L., & Husein, S. (2019). Problem-based learning approach with supported interactive multimedia in physics course: Its effects on critical thinking disposition. *Journal for the Education of Gifted Young Scientists, 7*(4), 1075–1089. https://doi.org/10.17478/jegys.627162

Hartt, M., Hosseini, H., & Mostafapour, M. (2020). Game on: Exploring the effectiveness of game-based learning. *Planning Practice & Research, 35*(5), 589–604. https://doi.org/10.1080/02697459.2020.1778859

Haruehansawasin, S., & Kiattikomol, P. (2018). Scaffolding in problem-based learning for low-achieving learners. *The Journal of Educational Research, 111*(3), 363–370. https://doi.org/10.1080/00220671.2017.1287045

Hui, H. B., & Mahmud, M. S. (2023). Influence of game-based learning in mathematics education on the students' cognitive and affective domain: A systematic review. *Frontiers in Psychology, 14*. https://doi.org/10.3389/fpsyg.2023.1105806

Jansen, M., Scherer, R., & Schroeders, U. (2015). Students' self-concept and self-efficacy in the sciences: Differential relations to antecedents and educational outcomes. *Contemporary Educational Psychology, 41*, 13–24. https://doi.org/10.1016/j.cedpsych.2014.11.002

Kang, N.-H. (2019). A review of the effect of integrated STEM or STEAM (science, technology, engineering, arts, and mathematics) education in South Korea. *Asia-Pacific Science Education, 5*(1), 6. https://doi.org/10.1186/s41029-019-0034-y

Kim, K.-S., Sin, S.-C. J., & Yoo-Lee, E. Y. (2014). Undergraduates' use of social media as information sources. *College & Research Libraries, 75*(4), 442–457. https://doi.org/10.5860/crl.75.4.442

Lasaiba, I. (2023). Menggugah kesadaran ekologis: Pendekatan biologi untuk pendidikan berkelanjutan. *Jendela Pengetahuan, 16*(2), 143–163. https://doi.org/10.30598/jp16iss2pp126-146

Lin, T. C., Liang, J. C., & Tsai, C. C. (2015). Conceptions of memorizing and understanding in learning, and self-efficacy held by university biology majors. *International Journal of Science Education, 37*(3), 446–468. https://doi.org/10.1080/09500693.2014.992057

Matthee, M., & Turpin, M. (2019). Teaching critical thinking, problem solving, and design thinking: Preparing IS students for the future. *Proceedings of the Annual Conference of the South African Institute of Computer Scientists and Information Technologists*, 30, 242–252.

Merrill, M. D. (2007). First principles of interaction: A synthesis. *Trends and Issues in Instructional Design and Technology, 2*, 62–71.

Munandar, A. (2023). Pengembangan aplikasi Android untuk mendukung pembelajaran listening Bahasa Inggris kelas XI SMAN 1 Boyan Tanjung. *Jurnal Penelitian Inovatif, 2*(3), 511–542. https://doi.org/10.54082/jupin.111

Nicolaou, C., Matsiola, M., & Kalliris, G. (2019). Technology-enhanced learning and teaching methodologies through audiovisual media. *Education Sciences, 9*(3), 196. https://doi.org/10.3390/educsci9030196

Rahmawati, Y., Zulhipri, Z., Hartanto, O., Falani, I., & Iriyadi, D. (2022). Students' conceptual understanding in chemistry learning using PhET interactive simulations. *Journal of Technology and Science Education, 12*(2), 303. https://doi.org/10.3926/jotse.1597

Robberts, A. S., & Van Ryneveld, L. (2022). Design principles for introducing 21st century skills by means of game-based learning. *Industry and Higher Education, 36*(6), 824–834. https://doi.org/10.1177/09504222221079210

Sahronih, S., Purwanto, A., & Sumantri, M. S. (2019). The effect of interactive learning media on students' science learning outcomes. In *Proceedings of the 2019 7th International Conference on Information and Education Technology* (pp. 20–24). ACM. https://doi.org/10.1145/3323771.3323797

Sailer, M., Schultz-Pernice, F., & Fischer, F. (2021). Contextual facilitators for learning activities involving technology in higher education: The C♭-model. *Computers in Human Behavior, 121*, 106794. https://doi.org/10.1016/j.chb.2021.106794

Setyosari, P. (2020). *Desain pembelajaran*. Bumi Aksara.

Simanjuntak, M. P., Hutahaean, J., Marpaung, N., & Ramadhani, D. (2021). Effectiveness of problem-based learning combined with computer simulation on students' problem-solving and creative thinking skills. *International Journal of Instruction, 14*(3), 519–534. https://doi.org/10.29333/iji.2021.14330a

Thaariq, Z. Z. A., Nurdiyanto, R., & Sulfa, D. M. (2023). Masalah-masalah dalam paradigma pembelajaran sains modern. *Jurnal Nyanadassana: Jurnal Penelitian Pendidikan, Sosial dan Keagamaan, 2*(2), 112–121. https://doi.org/10.59291/jnd.v2i2.38

Widiana, I. W., & Jampel, I. N. (2016). Improving students' creative thinking and achievement through the implementation of multiple intelligence approach with mind mapping. *International Journal of Evaluation and Research in Education (IJERE), 5*(3), 246. https://doi.org/10.11591/ijere.v5i3.4546

Yu, Z., Gao, M., & Wang, L. (2021). The effect of educational games on learning outcomes, student motivation, engagement and satisfaction. *Journal of Educational Computing Research, 59*(3), 522–546. https://doi.org/10.1177/0735633120969214

Zajda, J. (2021). Constructivist learning theory and creating effective learning environments. In *Globalisation and education reforms: Creating effective learning environments* (pp. 35–50). Springer. https://doi.org/10.1007/978-3-030-71575-5_3