

Review of Ecosystem Learning Media and Directions for Website-Based Innovation

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Submission : 14/01/2026

Revision : 13/07/2026

Accepted : 24/07/2026

ABSTRACT

Learning about ecosystems in high school biology is often abstract and difficult to visualize, so it requires interactive, accessible, and contextual learning media. This study aims to review various ecosystem learning media, analyze their validity, advantages, and limitations, and formulate directions for website-based development. A literature review was conducted on publications from 2020 to 2025 indexed in Google Scholar using Boolean operators. Of 183 initially identified articles, 39 met the inclusion criteria and were analyzed descriptively. The results show a strong trend toward digitalization, with most media demonstrating high validity (80–92%). In terms of learning outcomes, e-books (N-Gain 0.78), printed modules/LKPD (N-Gain 0.70), and interactive multimedia (N-Gain 0.68) showed high gains, while gamification (N-Gain 0.44) showed moderate gains. However, website-based and AR/3D media remain underexplored, with no N-Gain data available, indicating a significant research gap despite their great potential. This review offers a priority-based framework and evidence-based recommendations for teachers, curriculum developers, and educational technology designers. The synthesis emphasizes the need to develop interactive websites with AR/3D integration and expand gamification to target higher-order thinking skills.

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Keywords: high school Biology, ecosystem learning media, interactive website

Introduction

The core Biology learning, especially Ecosystem material, is an important subject at the high school level because it helps students understand the relationship between biotic and abiotic components and their impact on life ([Sa'diah et al., 2025](#); [Sigit et al., 2022](#)). However, several studies show that Ecosystem material is often considered abstract and difficult to visualize because it is not concrete, which causes learning difficulties for students ([Kamilah et al., 2023](#); [Miller & Yoon, 2023](#)). This also results in low conceptual understanding due to a lack of student engagement and activity ([Nufus et al., 2023](#)). This challenge requires teachers to use learning media that is interactive, accessible, and relevant to the characteristics of students in the digital generation.

Various types of learning media have been developed to support the learning of Ecosystem material, ranging from Student Worksheets (LKPD), printed modules, educational videos, interactive multimedia, to mobile-based learning ([Lathifah et al., 2025](#); [Norma et al., 2025](#); [Rahmawati & Wiharto, 2023](#)). However, most of these learning media are still one-way, lack interactivity, and are not integrated into a flexible platform for independent learning. On the other hand, students today show a strong preference for website-based learning media that allow access anywhere and anytime and support more personalized learning needs ([Abuhassna et al., 2020](#); [Yolanda et al., 2024](#)).

The use of websites as a learning medium offers a number of advantages, such as more diverse material presentation, multimedia integration, more flexible navigation, and evaluation features that can be tailored to needs ([Alenezi, 2020](#); [Lestari et al., 2024](#)). A number of studies also show that website-based learning media can improve conceptual understanding, learning motivation, and student independence in Biology subjects ([Putri et al., 2025](#); [Yanti et al., 2024](#)). However, studies related to the development of website-based Ecosystem learning media are still relatively limited, both in terms of design characteristics, effectiveness, and integration with the needs of high school students.

Previous studies have mostly focused on the development of non-web-based learning media, such as printed modules, videos, or non-browser-based mobile applications ([Putri et al., 2025](#); [Rahmawati, & Wiharto, 2023](#); [Tane et al., 2025](#)). However, the research gap remains quite wide and has been acknowledged by several previous studies. [Astuti & Ely \(2024\)](#) noted that digital technology has not yet been optimally integrated to create innovative ecosystem-based learning media. In line with this, [Septiana et al. \(2023\)](#) and [Jamhari et al. \(2023\)](#) acknowledge that the media used in ecosystem learning remain inefficient and unengaging for students, which results in low levels of conceptual understanding and learning motivation. Meanwhile, research on the development of websites for ecosystem materials, such as that conducted by [Azrai et al. \(2025\)](#), is still relatively new and very limited in number. Hence, it needs to be expanded to support more interactive and contextual learning. In addition, research that systematically examines the advantages, disadvantages, and development directions of Ecosystem learning media is still lacking, resulting in a research gap. It is important to bridge this gap so that the development of website-based learning media can be carried out in a targeted manner and based on empirical evidence.

Based on this background, this article aims to review various learning media that have been developed for Ecosystem material at the high school level, analyze their strengths and limitations, and identify potential directions for innovation in website-based media that could be applied. This study is expected to provide a conceptual basis and practical recommendations for teachers, researchers, and developers in designing website-based learning media that are in line with the characteristics of Ecosystem material and the needs of digital-generation students.

Methods

This study uses a literature review approach with descriptive analysis to examine and synthesize previous research results on the development of Biology learning media on Ecosystem material at the high school level. Scientific articles were searched through the Google Scholar database using a systematic search strategy with the following keywords and Boolean operators: ("Ecosystem learning media" OR "biology learning media" OR "Ecosystem teaching materials" OR "interactive media ecosystem") AND ("high school" OR "SMA" OR "secondary school") AND ("development" OR "validity" OR "effectiveness").

The articles obtained from the search were selected based on their titles and abstracts according to the following inclusion criteria: (1) articles published in national or international journals; (2) reporting results of learning media development; (3) discussing biology learning on Ecosystem material; (4) research conducted at the high school level (grades X–XII); and (5) articles published between 2020 and 2025. Articles were excluded if they were review articles or opinion pieces, did not focus on Ecosystem material, were conducted at the university level, or were published outside the specified timeframe. A total of 39 articles met the inclusion criteria and were included in this study. The complete selection process is presented in a PRISMA flow diagram (Figure 1).

Articles that met the inclusion criteria were thoroughly analyzed to identify the types of media developed, design characteristics, key findings, strengths and weaknesses, and recommendations reported. Validity and effectiveness data in this study were taken directly from the articles without recalculation and then analyzed using qualitative descriptive analysis techniques. Effectiveness data were represented by N-Gain scores reported in the original studies, with the following interpretation categories: $N\text{-Gain} > 0.7$ = high, $0.3\text{--}0.7$ = moderate, and < 0.3 = low ([Hake, 1999](#)). Each article was classified based on the learning media used, which were grouped into seven categories: (1) Android/Mobile applications, (2) Website/Web-based media, (3) Interactive Multimedia (including Adobe Flash, Articulate Storyline, and Canva-based media), (4) E-Book/Digital E-Module (including flipbooks and digital modules), (5) Printed Module/LKPD, (6) Gamification (educational games), and (7) 3D/AR/Pop-Up Visualization. These categories represent grouped learning media types based on their primary delivery format and technological characteristics. The analysis results were synthesized to map the distribution of media, validity, effectiveness, strengths and weaknesses matrix, and development recommendations based on research gaps. The synthesis of results was used to understand research trends and formulate the direction of innovation in developing a more interactive, adaptive, and biology-appropriate learning media Ecosystem based on websites at the high school level.

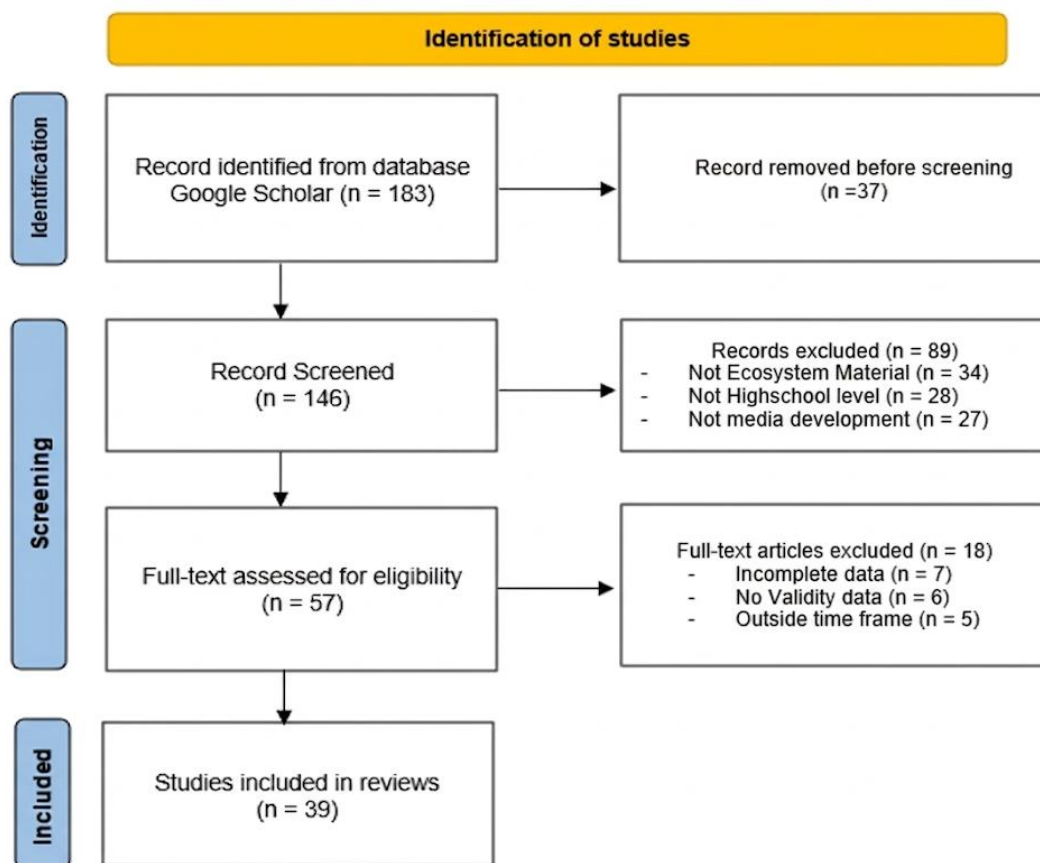


Figure 1. Prisma flow diagram

Results and Discussion

Analysis of 39 articles that met the inclusion criteria showed that there was diversity in the development of Biology learning media, especially in Ecosystem material at the high school level. This diversity showed the dynamics of research in the last five years (2020–2025), with a trend towards digitization. The distribution trend of media categories is explained in Figure 2.

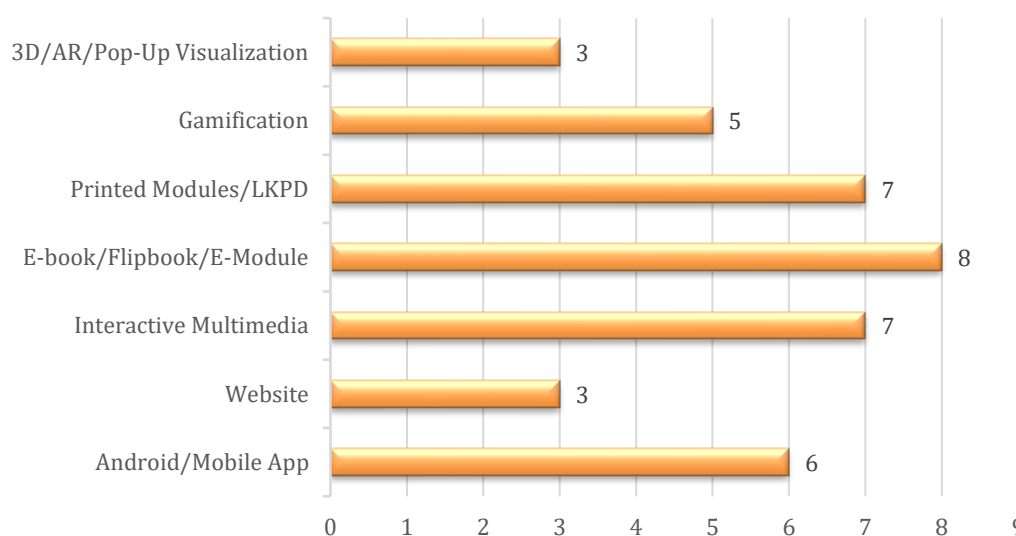


Figure 2. Learning media distribution

Figure 2 shows the dominance of digital media, with 32 articles (82.1%), e-books/flipbooks/digital e-modules (8 articles), interactive multimedia (7 articles), and Android applications (6 articles) as the top categories. This increasing trend is in line with the acceleration of digital transformation in education after the COVID-19 pandemic, where e-modules and interactive media increase student engagement by up to 30% through the visualization of abstract biological concepts ([Dewi & Saifuddin, 2022](#); [Riawan et al., 2025](#)). Interestingly, print media such as LKPD or modules still contribute significantly at 17.9% (7 articles), confirming their effectiveness in supporting contextual approaches and literacy. On the other hand, the development of website-based and 3D/AR media is still relatively limited (3 articles). In fact, both have great potential to provide flexibility of access, evaluation integration, and higher interactivity (Wicaksono & Wiratama, 2024; Widjaja et al., 2025). These findings confirm the trend of learning digitalization while also showing the lack of studies on website-based and AR/3D media, which have great potential for further development.

Learning Media Validity

The validity of learning media is an important indicator for assessing the feasibility and quality of innovations developed. The validity of the media used is useful for ensuring that each innovation is not only popular in form, but also feasible for use based on expert testing of aspects such as material, appearance, and language ([Ayunda & Lufri, 2024](#)). Validity levels were classified according to [Arikunto \(2013\)](#) and categorized as very high (81–100%), high (61–80%), moderate (41–60%), low (21–40%), or very low (0–20%). A synthesis of the results of the validity testing of the literature reviewed is described in Table 1.

Table 1. Learning media validity

No	Media Type	Average Validity (%)	Validity Level
1.	Android/Mobile App	85-92	Very High
2.	Website/Web-based	80-88	High
3.	Interactive Multimedia	84-90	Very High
4.	E-book/Digital E-module	82-91	Very High
5.	Printed Modules/LKPD	80-86	High
6.	Gamification	83-89	Very High
7.	3D/AR/Pop-Up Visualization	78-85	High

Note: Validity levels followed [Arikunto \(2013\)](#).

Based on Table 1, the majority of the 39 articles show that Ecosystem Biology learning media in high schools have high to very high validity with an average score above 80%. Digital media such as Android/Mobile Apps, e-books, and interactive multimedia received the highest scores (85–92%). These findings confirm the role of visual aspects, interactivity, and ease of use as key assessment factors ([Firmaningrum & Anggraito, 2022](#)). Print media such as LKPD/modules remain relevant with scores of 80–86%, especially in terms of material and language that support contextual learning. Conversely, website-based media and 3D/AR visualizations tend to score lower (78–88%). These findings indicate challenges in interactive design and feature integration ([Muhazaroh, 2023](#)). The lack of exploration in these two categories opens opportunities for further research to improve the validity of learning media.

Learning Media Effectiveness

The effectiveness of learning media is an indicator for assessing the extent to which media can improve students' conceptual understanding, learning motivation, and learning outcomes ([Pamela & Zulyusri, 2024](#)). A synthesis of the results of the effectiveness tests of the literature reviewed is described in Table 2.

Table 2. Learning media effectiveness

No	Media Type	Average N-Gain	Effectiveness Level	Number of Studies
1	Interactive Multimedia	0.68	High	1
2	Gamification	0.44	Moderate	1
3	E-book/Flipbook/E-Module	0.78	High	2
4	Printed Modules/LKPD	0.70	High	4

Note: N-Gain values are averages from studies that reported N-Gain using Hake (1999) formula.

Effectiveness analysis shows that most high school Ecosystem learning media are in the high category. E-books (N-Gain 0.78) rank highest with N-Gain > 0.7 (high effectiveness), followed by printed modules/LKPD (N-Gain 0.70) and interactive multimedia (N-Gain 0.68). Gamification falls into the moderate category (N-Gain 0.44). These findings confirm the role of interactivity, visualization, and contextual learning in deepening the understanding of Ecosystem concepts ([Manasikana et al., 2025](#); [Rahmah & Risnani, 2023](#)).

It is important to note that the N-Gain values presented are based on available data from articles that reported effectiveness using [Hake \(1999\)](#) formula. Based on the analysis of 39 articles, only 8 articles reported N-Gain scores. For several media categories, including Android/Mobile App, Website, and 3D/AR/Pop-Up Visualization, no articles reported N-Gain scores. Some of these articles reported effectiveness using other measures such as percentage scores, while others did not measure effectiveness at all. This finding itself indicates a significant research gap, particularly for website-based and AR/3D media, which have great potential for providing interactive and immersive learning but remain understudied in terms of their effectiveness ([Wicaksono & Wiratama, 2024](#); [Widjaja et al., 2025](#)).

Learning Media Advantages and Disadvantages

The analysis of effectiveness and validity not only shows trends in media use but also reveals advantages and disadvantages. The results of the analysis indicate that each category of media has specific advantages and disadvantages in supporting learning about Ecosystems at the high school level (Table 3).

Table 3. Advantages and disadvantages analysis

Learning Media Type	Advantages	Disadvantages
Android/ Mobile App	Easy access via smartphone, portable, supports independent learning with quizzes.	Simple features, limited device compatibility, requires a stable connection.
Website/ Web-based	Flexible access without installation, easy to update, integration of evaluation and discussion.	Minimal interactive design, effectiveness is not consistent, requires stable internet access.
Interactive Multimedia	Clearer visualization of abstract concepts, high interactivity.	Requires devices with sufficient specifications; the development process is relatively complex.
Digital E-book/ E-module	Practical, cost-effective printing, easy to share, text-image integration, and video.	Less interactive, high risk of boredom, requires specific equipment.
Printed Module/ LKPD	Supports contextual learning, does not depend on internet devices, relevant for science literacy.	Limited visualization, distribution costs, less flexible for updates.

Learning Media Type	Advantages	Disadvantages
Gamification	Enjoyable and capable of increasing motivation, engagement, and critical thinking skills.	Risk of distraction from the game, and relatively complex development.
3D/AR/ Pop-Up Visualization	Providing an immersive overview, understanding structural and abstract concepts.	Requires sophisticated equipment, limited access, and development is still ongoing.

Table 3 shows that each media category has strengths and challenges in the application of high school Ecosystem learning. Digital media (interactive multimedia, e-books, Android) excels in visualization, interactivity, and accessibility, but depends on devices and networks and requires technical skills. Websites have advantages in terms of access flexibility and content sustainability, as they can be easily updated according to the latest curriculum ([Lestari et al., 2024](#)). However, limitations lie in the lack of interactive design and the need for stable internet, so their effectiveness is not yet consistent ([Rahmawati & Wiharto, 2023](#)). Printed modules/student worksheets remain relevant for contextual learning and science literacy, despite their limitations in visualization and physical distribution. Gamification and AR/3D provide an immersive experience that enhances motivation and understanding of abstract concepts ([Banna & Subiantoro, 2025](#); [Rohmatulloh et al., 2022](#)). However, access is limited, and development requirements remain relatively complex. These findings emphasize the need for development strategies that balance the strengths and overcome the limitations of each category. In addition, these findings also show that there are media with great potential, but they have not been widely explored.

Synthesis of Limitations and Development Directions

The analysis results show that although the majority of Ecosystem learning media are valid and effective, there are still limitations in several categories. Digital media face challenges in terms of device and network dependency, while LKPD is limited in terms of visualization and interactivity ([Prahani et al., 2022](#); [Suryawati et al., 2024](#)). Websites and AR/3D also show weaknesses in interactive design and feature integration. However, not all limitations have the same level of urgency, so a priority scale for the future development of Ecosystem learning media is needed ([Sa'adah et al., 2023](#)). The priority levels (high, medium, and low) were determined based on three criteria: research gap magnitude, urgency for improving learning quality, and development feasibility.

Table 4. Synthesis of limitations and development directions

Limitations of Learning Media	Development Directions	Priority
Websites and AR/3D technology are still under-explored and have low effectiveness.	Development of interactive websites with automatic evaluation and AR/3D integration.	High
Validity has not assessed the sustainability of media use.	Research on updates to content and school system integration.	Medium
Digital media lacks contextual relevance to the real world.	Integration of digital media with local or hybrid practices with LKPD.	Medium
Gamification is limited and does not yet measure critical skills.	Ecosystem-based gamification research collaboration.	Low - Middle

The results of the study show that learning media for high school Ecosystem material has developed with a strong trend toward digitalization, high validity, and relatively good effectiveness. However, there are still a number of gaps that need to be addressed. The main

priority is given to website-based and AR/3D media, which, despite having sufficient validity and low effectiveness, have not been widely researched. In fact, both have great potential to provide interactive and immersive learning ([Wicaksono & Wiratama, 2024](#); [Widjaja et al., 2025](#)). The secondary priority covers the aspects of sustainability and contextualization of digital media. Currently, research emphasizes content and appearance more than content updates, school system integration, or practical application ([Lestari et al., 2020](#); [Mantang et al., 2024](#)). Low to medium priority is given to gamification, which has been proven to increase motivation but is still limited in measuring critical thinking and collaboration skills ([Rohmatulloh et al., 2022](#)). Thus, the direction of media development needs to focus on optimizing websites and AR/3D by strengthening the sustainability of digital media, as well as expanding gamification to enrich real learning experiences in the student environment.

Limitation

This review is limited to articles indexed in Google Scholar. The inclusion of additional databases such as Scopus or Web of Science in future studies would enhance the comprehensiveness and reproducibility of the review. Additionally, the effectiveness analysis is constrained by the limited availability of N-Gain data. Several media categories, including Android/Mobile App, Website, and 3D/AR/Pop-Up Visualization, lacked studies reporting N-Gain scores using Hake's (1999) formula. Future research should address this gap by conducting effectiveness studies on these under-researched media categories.

Conclusion

Ecosystem learning media in high schools have developed with a strong trend toward digitization, demonstrating high validity and moderate to high effectiveness. Digital media such as interactive multimedia, e-books, and gamification effectively enhance motivation and conceptual understanding, while printed worksheets/modules remain relevant for contextual learning. However, website-based and AR/3D media remain underexplored despite their great potential for interactive and immersive learning.

This review synthesizes the current landscape of ecosystem learning media research and provides a priority-based framework to guide future development. It also offers evidence-based recommendations for teachers, curriculum developers, and educational technology designers in selecting and developing appropriate learning media. For future research, we recommend conducting experimental studies on website-based media integrated with AR/3D features to test their effectiveness on various learning outcomes. In addition, researchers should focus on developing sustainable media that can be regularly updated and integrated with school systems. Hybrid approaches that combine digital media with contextual local content also warrant further exploration. Furthermore, gamification should be designed to target higher-order thinking skills and collaboration explicitly. This review highlights website-based ecosystem learning media as a promising yet underexplored innovation with strong potential to bridge interactivity, sustainability, and contextual learning.

Generative AI Disclosure

The use of artificial intelligence in this manuscript is limited to language translation and editing to improve readability, without affecting the scientific substance, data analysis, or research interpretation.

References

Abuhassna, H., Al-Rahmi, W. M., Yahya, N., Zakaria, M. A. Z. M., Kosnin, A. B. M., & Darwish,

- M. (2020). Development of a new model on utilizing online learning platforms to improve students' academic achievements and satisfaction. *International Journal of Educational Technology in Higher Education*, 17(1). <https://doi.org/10.1186/s41239-020-00216-z>
- Alenezi, A. (2020). The role of e-learning materials in enhancing teaching and learning behaviors. *International Journal of Information and Education Technology*, 10(1), 48–56. <https://doi.org/10.18178/ijiet.2020.10.1.1338>
- Arikunto, S. (2013). *Prosedur Penelitian: Suatu Pendekatan Praktik* (4th ed.). Rineka Cipta.
- Astuti, D. A. T., & Ely., R. (2024). Development of class X ecosystem e-catalog at SMA Negeri 12 Semarang. *Journal of Biology Education*, 13(2), 165–174. <https://journal.unnes.ac.id/sju/index.php/ujbe>
- Ayunda, S. N., & Lufri. (2024). Meta-analisis: validitas pengembangan e-booklet pembelajaran biologi untuk peserta didik SMA. *Al-Jahiz: Journal of Biology Education Research*, 5(2), 152–164. <https://doi.org/10.32939/symbiotic.v5i1>
- Azrai, E. P., Aulya, N. R., Suryanda, A., & Safitri, F. A. (2025). ECO-STEAM: A steam-based digital learning website for ecosystem topics. *Journal of Technology and Science Education*, 15(2), 399–419. <https://doi.org/10.3926/jotse.3065>
- Banna, N. Z. Al, & Subiantoro, A. W. (2025). Implementation of game-based learning in biology learning to improve the ability of high school students: A narrative literature review. *Bioedukasi: Jurnal Pendidikan Biologi*, 18(1), 95–107. <https://jurnal.uns.ac.id/bioedukasi/article/view/88141>
- Dewi, N. K., & Saifuddin, M. F. (2022). High school biology learning media during the Covid-19 pandemic in Indonesia: systematic literature review. *Bioedukasi: Jurnal Pendidikan Biologi*, 15(2), 92–102. <https://doi.org/10.20961/bioedukasi-uns.v15i2.59994>
- Firmaningrum, W. S., & Anggraito, Y. U. (2022). Development of android-based learning media on ecosystem materials to train students' cognitive ability. *Jurnal of Biology Education*, 11(3), 350–359. <http://journal.unnes.ac.id/sju/index.php/ujbe>
- Hake, R. R. (1999). *Analyzing change/gain scores*. AREA-D American Education Research Association's Division D, Measurement and Research Methodology.
- Jamhari, M., Dewi, Y. M., & Astija. (2023). Development of audiovisual learning media on ecosystem topic at SMA Negeri 1 Sigi. *International Journal of Science and Research Archive*, 10(2), 181–184. <https://doi.org/10.30574/ijrsra.2023.10.2.0945>
- Kamilah, S. F., Wahyuni, I., & Ratnasari, D. (2023). Pengembangan media pembelajaran interaktif berbasis website menggunakan Google Sites pada materi ekosistem kelas X SMA. *Biodik: Jurnal Ilmiah Pendidikan Biologi*, 9(3), 169–181. <https://doi.org/10.22437/biodik.v9i3.25523>
- Lathifah, S. S., Retnowati, R., & Suryani, S. (2025). Development of interactive multimedia based on problem-based learning on ecosystem material to improve the analytical skills of senior high school students. *Equator Science Journal*, 3(1), 28–35. <https://doi.org/10.61142/esj.v3i1.147>
- Lestari, I. D., Noviaty, W., & Novita, M. (2024). Pengembangan media web google sites berbasis project-based learning untuk siswa SMA kelas X. *Jurnal Pendidikan MIPA*, 14(14), 1123–1131. <https://doi.org/10.37630/jpm.v14i4.2108>
- Lestari, W. D., Yuhanna, W. L., & Lukitasari, M. (2020). Pengembangan media bio pop-up book terintegrasi science, environment, technology, and society (SETS) pada pembelajaran Biologi materi daur biogeokimia. *Jurnal Edukasi Matematika Dan Sains*, 8(2), 130–139. <https://doi.org/10.25273/jems.v8i2.7442>
- Manasikana, A., Marsiyah, D. A. A., Amaliyah, I. R., & Prayogo, M. S. (2025). Analisis penggunaan media interaktif berbasis Canva pada mata pelajaran IPAS materi ekosistem di MIS Al-Azhar Ajung Jember. *Jurnal Ilmiah Literasi Indonesia*, 1(2), 523–530. <https://doi.org/ojs.indopublishing.or.id/index.php/jili/article/view/410>
- Mantang, B. S., Utina, R., & Latjompoh, M. (2024). Application of the inquiry learning model to improve the critical thinking ability of class X ecosystem material students at MA Alkhairaat Bolangitang Barat. *Bioedukasi: Jurnal Pendidikan Biologi*, 17(1), 13–21.

<https://jurnal.uns.ac.id/bioedukasi/article/view/75428>

- Miller, K. M., & Yoon, S. A. (2023). Teaching complexity in biology through agent-based simulations: the relationship between students' knowledge of complex systems and metamodeling knowledge. *Frontiers in Education*, 8. <https://doi.org/10.3389/educ.2023.1198307>
- Muhazaroh, I. (2023). Pemanfaatan media digital dalam pembelajaran biologi di era globalisasi. *Jurnal Penelitian Multidisiplin*, 2(1), 153–157. <https://doi.org/10.58705/jpm.v2i1.116>
- Norma, Lihang, A., & Pendong, D. F. (2025). Pengembangan perangkat pembelajaran berbasis keterampilan proses pada materi ekosistem kelas X Biologi SMA Negeri 11 Enrekang. *JURIPEN: Jurnal Riset Rumpun Ilmu Pendidikan*, 4(1), 406–422. <https://prin.or.id/index.php/JURIPEN>
- Nufus, L., Agustina, R., & Dewi, E. (2023). Pengembangan media pembelajaran multimedia interaktif pada materi ekosistem di SMA Negeri Delima Kabupaten PIDIE. *Jurnal Biomafika*, 1(1), 1–9. <https://journal.unigha.ac.id/index.php/BIOMAFIKA/index>
- Pamela, A. Z., & Zulyusri. (2024). Meta-analisis: validitas media booklet pada pembelajaran biologi (tahun 2013-2023). *SYMBIOTIC: Journal of Biological Education and Science*, 5(1), 84–95. <https://sybiotic.iainkerinci.ac.id/index.php/sybiotic/index>
- Prahani, B. K., Rizki, I. A., Nisa, K., Citra, N. F., Alhusni, H. Z., & Wibowo, F. C. (2022). Implementation of online problem-based learning assisted by digital book with 3D animations to improve student's physic problem-solving skills in magnetic field subject. *Journal of Technology and Science Education*, 12(2), 379–396. <https://doi.org/10.3926/jotse.1590>
- Putri, F., Alberida, H., Yogica, R., & Anggryani, R. (2025). Pengembangan media pembelajaran interaktif menggunakan aplikasi Emaze tentang materi ekosistem untuk peserta didik SMAN 1 LUHAK NAN DUO. *Biogenerasi: Jurnal Pendidikan Biologi*, 10(2), 1048–1051. <https://e-journal.my.id/biogenerasi>
- Rahmah, S., & Risnani, L. Y. (2023). Development of educational game-based learning media to improve mastery of ecosystem material in high school students. *Jurnal Praktisi Pendidikan*, 2(2), 84–98. <https://doi.org/10.58362/hafecspost.v2i2.42>
- Rahmawati, L. H., & Wiharto, M. (2023). Pengembangan media pop up book berbasis video animasi 3d materi daur biogiokimia kelas X SMA. *Innovasi Sains Dan Pembelajarannya: Tantangan Dan Peluang*, 608–619. <https://journal.unm.ac.id/index.php/semnasbio/article/view/1048>
- Riawan, I. M. O., Juniartina, P. P., Agustini, K., Sudhata, I. G. W., & Putra, A. A. A. W. (2025). Pengembangan e-modul Biologi SMA: Kajian sistematis literatur. *Jurnal Pendidikan Biologi Undiksha*, 12(1), 31–45. <https://ejournal.undiksha.ac.id/index.php/JJPB/index%0A>
- Rohmatulloh, G., Siregar, N. F., & Widodo, A. (2022). Inovasi media pembelajaran 3 dimensi berbasis teknologi pada pembelajaran biologi. *Biodik: Jurnal Ilmiah Pendidikan Biologi*, 8, 139–146. <https://online-journal.unja.ac.id/biodik/article/view/19114>
- Sa'adah, A. A., Karyanto, P., & Nurmiyati. (2023). Pengembangan multimedia interaktif berbasis articulate storyline pada pembelajaran ekologi SMA kelas X. *Bio-Pedagogi: Jurnal Pembelajaran Biologi*, 12(1), 10–25. <https://jurnal.uns.ac.id/pdg/article/view/69720/pdf>
- Sa'diah, S. A., Chusni, M. M., & Kariadinata, R. (2025). Pengaruh model pembelajaran problem based learning terhadap hasil belajar siswa pada materi ekosistem. *International Journal of Science*, 3(2). <https://doi.org/10.70115/ijsta.v3i2.393>
- Septiana, E. W., Sofiyana, M. S., & Sulistiana, D. (2023). Scrabook learning media in class X ecosystem materials. *JARES (Journal of Academic Research and Sciences)*, 8(1), 25–34. <https://ejournal.unisbablitar.ac.id/index.php/jares>
- Sigit, D. V., Ristanto, R. H., & Mufida, S. N. (2022). Integration of project-based e-learning with STEAM: An innovative solution to learn ecological concept. *International Journal of Instruction*, 15(3), 23–40. <https://doi.org/10.29333/iji.2022.1532a>
- Suryawati, C. T., Ma'rifatin, I. K., Susilo, A. T., Asrowi, & Surur, N. (2024). Enhancing

- effectiveness of guidance and counseling services through web-based interactive media. *Ingenierie Des Systemes d'Information*, 29(1), 37–48. <https://doi.org/10.18280/isi.290105>
- Tane, D., Utina, R., Hamidun, M. S., Latjompoh, M., Yusuf, F. M., & Katili, A. S. (2025). Pengembangan modul pembelajaran biologi pada materi interaksi dalam ekosistem berbasis pendekatan contextual teaching and learning (CTL) kelas X di SMA Negeri 1 Tilango. *Algoritma: Jurnal Matematika, Ilmu Pengetahuan Alam, Kebumihan Dan Angkasa*, 3(1), 91–98. <https://doi.org/10.62383/algoritma.v3i1.358>
- Wicaksono, S. A., & Wiratama, R. (2024). Pemanfaatan media digital interaktif dalam pembelajaran biologi untuk meningkatkan motivasi siswa. *Jurnal Cakrawala Pendidikan Dan Biologi*, 1(3), 25–34. <https://ejournal.aripi.or.id/index.php/jucapenbi/article/view/183>
- Widjaja, Y., Junaidi, & Solihatin, E. (2025). Perancangan model pembelajaran Biologi berbasis augmented reality. *Proceedings of the 3rd International Conference on Pesantren (3rd ICOP) 2025*, 11. <https://ejournal.darunnajah.ac.id/index.php/icop/article/view/582>
- Yanti, F., Lufri, Ahda, Y., Sepriani, R., & Ockta, Y. (2024). Web-based biology learning media for distance education_ Systematic literature review. *Multidisciplinary Reviews. Учредители: JABB-Journal of Animal Behaviour and Biometeorology*, 8(5), 2025109. <https://doi.org/10.31893/multirev.2025109>
- Yolanda, D., Ferry, D., Haryanto, T., & Biologi, P. T. (2024). Analisis preferensi siswa terhadap media pembelajaran berdasarkan gaya belajar. *Eduproxima: Jurnal Ilmiah Pendidikan IPA*, 6(4), 1428–1438. <https://jurnal.stkippgritulungagung.ac.id/index.php/eduproxima/article/view/5405>