

Development of DNA Sequencing E-Book for Critical Thinking and Environmental Literacy

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Abstract: This study aims to develop a Bio-Genetics Ebook based on In Silico DNA Sequencing and analyze its influence on critical thinking and environmental literacy of grade X students at SMA Negeri 30 Jakarta. The learning media in the form of an ebook produced examines and analyzes populations and species by utilizing computing technology in the form of DNA sequencing using NCBI in DNA analysis and Mega to obtain a phylogenetic tree. The student needs analysis stage revealed that students need interactive learning media that is easy to carry anywhere. The design stage produced an ebook design with superior content of in silico DNA sequencing, bioinfo, case studies, and quizzes. From the results of the media and material feasibility test carried out at the development stage, the results were 84% and 89% respectively. The ebook was considered suitable for use and only required minor adjustments. Educators and students evaluated the small group trial, with scores of 84% and 82% respectively, indicating that the trial could be used as a biology learning medium. The use of In Silico DNA Sequencing-based Bio-Genetics Ebook on critical thinking skills and environmental literacy of students has increased, according to the results of the MANOVA hypothesis test which also showed a significance value of $0.00 < 0.05$. Thus, the developed ebook is suitable for use as a biology learning medium and to improve critical thinking skills and environmental literacy of students.

Keywords: Critical thinking; DNA sequencing; E-Book; Environmental literacy; Hannafin & Peck

Introduction

In the era of globalization and technological advancement, the main challenge facing the world is how to prepare the younger generation to face increasingly complex environmental problems, such as climate change and declining biodiversity (Weiskopf et al., 2020; Kim et al., 2024). For this reason, critical thinking skills and environmental literacy are very important. Critical thinking allows students to evaluate, analyze, and solve problems independently (O'Reilly et al., 2022; Altun & Yildirim, 2023). In addition, environmental literacy teaches an understanding of the relationship between humans and the environment and

the impact of human activities on ecosystems (Van De Pol et al., 2023; Ming et al., 2024). The results of initial observations at SMA Negeri 21 Jakarta showed that the low critical thinking skills and environmental literacy of students were due to the lack of variation in teaching models and the inability of students to relate material to real environmental issues (Salvatore & Wolbring, 2022; Ginting et al., 2023), addition, some students want technology-based learning, such as e-books, which can improve their understanding and involvement in environmental issues.

E-books as a learning medium offer various advantages, such as ease of access, interactivity, and environmental sustainability. One example of the

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innovative use of e-books is by using in silico DNA sequencing software. This technology helps students analyze biodiversity more effectively without the need for direct laboratory experiments, and provides insight into species adaptation and the impact of climate change on genetic diversity. In silico DNA sequencing-based e-books can be a solution (Duncavage et al., 2023; Alam et al., 2022). This e-book provides easy access, interactivity, and contains DNA sequencing concepts to study biodiversity effectively (Kreherwinkel et al., 2019; Gostel & Kress, 2022). E-books as a learning medium offer various advantages, such as easy access, interactivity, and environmental sustainability (Haleem et al., 2022; Al Mulhim & Zaky, 2023). One example of the innovative use of e-books is by using in silico DNA sequencing software (Marques et al., 2024; Malamon, 2024).

In silico DNA sequencing is a technique used to analyze DNA sequences without a direct laboratory, which is effective in monitoring biodiversity (Theissinger et al., 2023; Kalendar et al., 2024). This technology helps students analyze biodiversity more effectively without the need for direct laboratory experiments, and provides insight into species adaptation and the impact of climate change on genetic diversity. The use of interactive e-books with multimedia content can improve students' critical thinking skills and environmental literacy, as well as help them understand environmental impacts scientifically and practically (Rubini et al., 2023; Cahyono et al., 2024).

Method

This study aims to develop learning media in the form of an Ebook Bio-Genetics based on DNA Sequencing in silico that can encourage students to think critically and increase awareness of environmental issues through a trial implemented at SMA Negeri 21 Jakarta in the even academic year of 2024-2025. The target of the study was grade X students with the distribution of needs analysis questionnaires in grade XI and two biology educators. The trial was conducted with a sample of 30 students for small group tests and 60 students for effectiveness tests. This study is a development research using an adaptation of the Hannafin and Peck model (1988) in (Hyun et al., 2025). The Hannafin and Peck model consists of 3 phases, namely needs analysis, design, and development and implementation. The three phases are connected to the evaluation and revision phases. In the third phase, the development and implementation stage, the designed product is validated and given criticism or suggestions by experienced validators or experts in the material and

media experts. The revised product was tested limited to students of class X SMAN 21 Jakarta, if there were criticisms or suggestions from media experts and material experts, the ebook was immediately revised.

Table 1. Scoring Criteria

Score	Criteria
85-100	Very Eligible
70-84.90	Eligible
55-69.90	Fair
40-54.90	Less Eligible
25-39.90	Not Eligible

Data obtained from the results of the Pretest-posttest of critical thinking and environmental literacy using SPSS V 25.0, with the following steps:

Prerequisite Test

The data that has been collected is first subjected to prerequisite tests including normality tests, homogeneity of variance, and homogeneity of covariance matrix. The normality test aims to determine whether the data in the experimental class and control class come from a normally distributed population or not. The normality test used is the Kolmogorov-Smirnov test with a significance value of >0.05 . The homogeneity test is carried out to determine whether the data obtained from the two groups have the same variance or not. The test consists of two stages, namely the homogeneity of variance and covariance matrix tests. The homogeneity of variance test uses the Leven' Test with a significance value of >0.05 . The homogeneity test of the covariance matrix utilizes the Box's M test. The Box's M test is used to assess the MANOVA hypothesis which requires uniformity of the covariance matrix of the dependent variable between groups. The decision-making criteria in this test if the significance value is >0.05 .

Hypothesis Testing

Hypothesis testing is done through the MANOVA test, which is a multivariate form of ANOVA. The MANOVA test functions to assess the relationship between several independent variables totaling two or more variables simultaneously.

Effectiveness Test (N-gain)

Normalized gain or N-gain is used to evaluate the improvement of critical thinking and environmental literacy of students after going through the pretest and posttest. The data will be transformed into an N-gain value (g).

Result and Discussion

This study developed an e-book Bio-Genetics based on DNA sequencing in silico to improve critical thinking skills and environmental literacy of students at SMA Negeri 21 Jakarta. The development model used adapted the Hannafin & Peck (1988) in (Moses Adeleke Adeoye et al., 2024) procedure, which includes the stages of needs analysis, design, development, and implementation, complemented by evaluation and revision at each stage. The results of the needs analysis were carried out by distributing questionnaires to 30 grade X students who had studied the concept of biodiversity. The analysis showed that although the use of technology by students was quite high, there was still room to improve its use in biology learning through e-books (Abdulrahman et al., 2020; Liu et al., 2024; Coman et al., 2020). Students also showed great interest in the use of e-books as a learning medium (Al Kamil et al., 2023). In addition, environmental issues were considered very important by students and could be integrated into the development of e-books (Şeker, 2023; Mensah, 2019). However, some students were still unfamiliar with the concept of DNA sequencing in silico, which indicated the need to introduce this technology further (Vashisht et al., 2023; Ally et al., 2024).

Educators usually use media such as PowerPoint and printed books, and often provide PDF files as supporting learning resources (Jones, 2003; Pantiwati et al., 2024). Therefore, to attract students' interest, educators need to provide interesting technology-based content. Respondents in this study consisted of 2 biology educators who teach class X of the Independent Curriculum. The questionnaire provided included 10 questions. Educators revealed that biodiversity material is often difficult for students to understand, especially when faced with analytical questions or assignments. To support learning, educators often share PDF files. The results of observations show that the media currently used is less effective and needs improvement, such as adding variations in the material. The development of learning media will be adjusted to the facilities available at the school, such as laptops, smartphones, projectors, and internet networks.

Table 3. Media and Material Testing

Aspect	Indicator	Assessor		Average score	Mark	Information
		1	2			
Media	Design	18	19	289	84	Worthy
	Graphics	20	18	380		
	User convenience	19	17	278		
Material	Curriculum	20	19	346.60	89	Not feasible
	Material	18	20	380		
	Language	16	19	299		

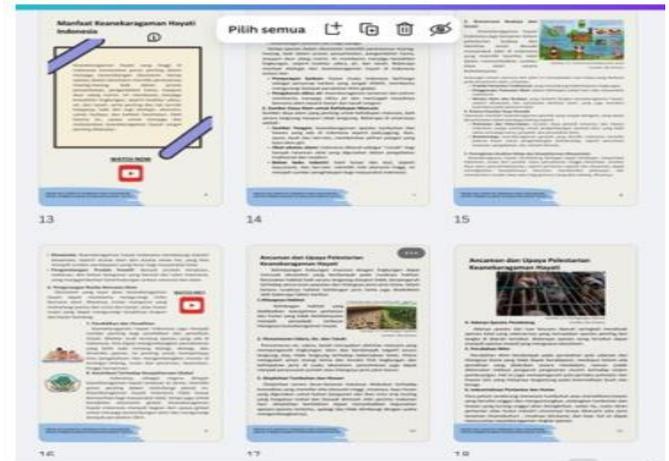


Figure 1. Draft ebook

The development and implementation stage of the ebook was found in the experimental class of class X-7 and X-3 and the control class X-7 and X-3 using the ebook published by the Ministry of Education and Culture with a scientific approach. In order to find out the differences in critical thinking skills and environmental literacy, a pretest and posttest were conducted on each group. The results of the study are shown in the following table.

Table 2. Results of Descriptive Analysis

Statistics	Critical thinking		Environmental literacy	
	Control	Experiment	Control	Experiment
Mean	66.00	83.67	83.87	92.00
Median	60.00	90.00	85.00	90.00
Standard deviation	12.86	5.65	5.92	5.50
varians	165.51	99.88	35.15	30.34
Minimum value	40	50	60	80
Maximum value	90	90	90	90

At the development stage includes validation by biology education lecturers who have expertise in the field of materials and media.

Based on the table, it can be interpreted that the DNA sequencing-based bio-genetics ebook containing biodiversity learning in the media is stated as feasible and the material is stated as very feasible to use with a few revisions. Furthermore, the ebook was tested on a small group of 30 students and 2 educators with the following results.

Table 4. Results of the Educator Trial

Aspect	Percentage	Category
Appearance	86.30	Very Worthy
Material	85.65	Very Worthy
Benefit	83	Worthy
Average	84.08	Worthy

Table 5. Results of Student Trials

Aspect	Percentage	Category
Appearance	84.50	Worthy
Material	87.33	Very Worthy
Benefit	76.50	Worthy
Average	81.46	Worthy

Based on the table above, it can be interpreted that the in silico DNA sequencing-based bio-genetics ebook

Table 6. Results of the Normality Test

Class	α	Significance of normality	Information
Pretest control	0.05	Critical thinking	Data Normal
Posttest control		0.021	Environmental literacy
Pretest Experiment		0.070	0.200
Posttest Experiment		0.093	
		0.200	

Table 7. Results of the Homogeneity Test

Data	α	Significance	Information
Critical Thinking	0.05	0.51	Homogeneous data
Environmental Literacy		0.48	

Table 8. Results of the Covariance Homogeneity Test

Box s M test	f	Significance
5.187	1.66	0.17

Based on the homogeneity covariance test table, the significance value obtained is $0.17 > 0.05$. In accordance with the basis for decision making, the covariance matrix of the dependent variable has the same variance (homogeneous), so that the MANOVA analysis as a hypothesis test can be continued. The criteria for meeting the hypothesis test have been met, the author continues the test, namely the hypothesis using the MANOVA test. The following are the results of the test of effects between subjects in testing the first and second hypotheses shown in the following table.

is suitable for use as a learning medium with minor revisions. The theoretical feasibility test was conducted to assess the validity and reliability of the In Silico DNA Sequencing-based Bio-genetics Ebook to improve students' critical thinking skills and environmental literacy. The feasibility test aims to test the extent to which the ebook can support the objectives set in this study, namely improving students' critical thinking skills and environmental literacy.

Based on the table of normality test results, it is known that the significance value of critical thinking and environmental literacy is greater than 0.05, so it is said that all research data is normally distributed. The homogeneity of variance test uses the Leven' test with a significance value of >0.05 .

The homogeneity test results table shows that the significance value of critical thinking skills and environmental literacy is greater than 0.05. It is interpreted as both data vary equally or are homogeneous. Then a homogeneity test of the covariance matrix is carried out as a requirement for the MANOVA test. The homogeneity test of the covariance matrix is seen from the Box's M Test Covariance test. With a significance value > 0.05 .

Table 9. Test Results of the Test of Between Subjects Effects

Variables	f	Significance (p value)
Critical Thinking	11.722	0.001
Environmental Literacy	13.037	0.001

The test result table shows that the thinking ability of students who are taught by the E-Book Genetics based on DNA sequencing in silico produces a significance value of less than 0.05. This shows that there is a significant difference in critical thinking ability between the use of the E-Book Genetics based on DNA sequencing in silico and the Biodiversity Textbook (Valdez-Baez et al., 2022; Heather & Chain, 2016; Akpoviri et al., 2023). Likewise, the significance value of environmental literacy of students' scientific attitudes is 0.05. The third test used multivariate testing is shown in the following table 10.

Based on the table 10, it is known that the results of the Pillai's Trace, Wilks' Lambda, Hotelling's Trace, Roy's Largest Root tests have a significance value of $0.000 < 0.05$. So according to the basis for decision

making, it can be concluded that there is a significant influence of the DNA Sequencing-Based Genetics E-Book on the critical thinking skills and environmental literacy of class X students of SMA Negeri 30 Jakarta.

The results of the effectiveness analysis on critical thinking skills and environmental literacy are as follows table 11.

Table 10. MANOVA Test Results

	Effect	Value	f	Significance
Ebook Bio-Genetics Based on DNA Sequencing	Pillai's Trace	0.264	11.848	0.000
	Wilks Lambda		0.706	
	Hotelling's Trace		0.416	
	Roy's Largest Root		0.416	

Table 11. Results of N-gain Critical Thinking and Environmental Literacy

	N- Gain	Control class Interpretation	N- Gain	Experiment Interpretation
Critical Thinking	0.33	Currently		
Environmental Literacy	0.26	Low		

Based on the table shown that critical thinking skills and environmental literacy are based on control and experimental classes. The results obtained in critical thinking in the control class have an N-gain value of 0.33 with a moderate interpretation and the experimental class has an N-gain value of 0.83 with a high interpretation. Thus, the average N-gain value of the experimental class is superior to the control class. While in the results of environmental literacy (Khairani et al., 2023), the control class has an N-gain value of 0.26 with a low interpretation and the experimental class is 0.55 with a moderate interpretation. This shows that the experimental class in the results of environmental literacy N-gain is superior to the control class (Wahyu et al., 2020; Pan & Hsu, 2020). So, it can be concluded that there is an increase in critical thinking and environmental literacy in students (Ardiansyah et al., 2024; Chao, 2024).

Conclusion

The Bio-genetics e-book based on DNA Sequencing In Silico that was developed is suitable for use as a media and source of biology learning. The use of e-books has been proven to improve critical thinking skills and environmental literacy of students of SMA Negeri 21 Jakarta class X. The increase in critical thinking skills consecutively includes the dimensions of interpretation, analysis, evaluation, inference, explanation, and self-regulation. The increase in environmental literacy consecutively occurs in the dimensions of environmental knowledge, attitudes towards the environment, cognitive skills, and behavior towards the environment.

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Author Contributions

Conceptualization, methodology, validation, formal analysis, investigation, resources, D. F. H.; data curation, writing—original draft preparation, writing—review and editing, visualization, H. I., R. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest

The authors declare no conflict of interest.

References

- Abdulrahman, M. D., Faruk, N., Oloyede, A. A., Surajudeen-Bakinde, N. T., Olawoyin, L. A., Mejabi, O. V., Imam-Fulani, Y. O., Fahm, A. O., & Azeez, A. L. (2020). Multimedia tools in the teaching and learning processes: A systematic review. *Heliyon*, 6(11), e05312. <https://doi.org/10.1016/j.heliyon.2020.e05312>
- Akpoviri, F. I., Baharum, S. N., & Zainol, Z. A. (2023). Digital Sequence Information and the Access and Benefit-Sharing Obligation of the Convention on Biological Diversity. *NanoEthics*, 17(1), 1. <https://doi.org/10.1007/s11569-023-00436-3>
- Al Kamil, M. N., Izzaty, R. E., & Patmawati, N. (2023). Digital Picture Storybooks, Can Increase Students' Self-Efficacy and Interest in Learning? *Jurnal Ilmiah Sekolah Dasar*, 7(1), 35–45. <https://doi.org/10.23887/jisd.v7i1.54457>
- Al Mulhim, E. N., & Zaky, Y. A. M. (2023). Sustainability in E-Learning: E-Books and Academic Procrastination among Secondary Students.

- Sustainability*, 15(20), 14668. <https://doi.org/10.3390/su152014668>
- Alam, K., Hao, J., Zhong, L., Fan, G., Ouyang, Q., Islam, M. M., Islam, S., Sun, H., Zhang, Y., Li, R., & Li, A. (2022). Complete genome sequencing and in silico genome mining reveal the promising metabolic potential in *Streptomyces* strain CS-7. *Frontiers in Microbiology*, 13, 939919. <https://doi.org/10.3389/fmicb.2022.939919>
- Ally, O., Kanoi, B. N., Kamath, S., Shiluli, C., Ndombi, E. M., Odiere, M., Misinzo, G., Nyanjom, S. G., Kumar, C. K., Ochola, L., Lolabattu, S. R., & Gitaka, J. (2024). Development of a rapid and highly sensitive nucleic acid-based diagnostic test for schistosomes, leveraging on identical multi-repeat sequences. *Frontiers in Parasitology*, 3, 1361493. <https://doi.org/10.3389/fpara.2024.1361493>
- Altun, E., & Yildirim, N. (2023). What does critical thinking mean? Examination of pre-service teachers' cognitive structures and definitions for critical thinking. *Thinking Skills and Creativity*, 49, 101367. <https://doi.org/10.1016/j.tsc.2023.101367>
- Ardiansyah, A. I., Putra, A. K., & Nikitina, N. (2024). Investigating Problem-Based Learning Model's Impact on Student's Critical Thinking Skills in Environmental Conservation Context. *Jambura Geo Education Journal*, 5(2), 87-103. <https://doi.org/10.37905/jgej.v5i2.26110>
- Cahyono, B. T., Qodr, T. S., & Budiarto, M. K. (2024). Improving the Critical Thinking Ability of Vocational High School Students through Digital Teaching Material. *Journal of Education Research and Evaluation*, 8(1), 143-153. <https://doi.org/10.23887/jere.v8i1.61457>
- Chao, Y.-L. (2024). Different tracks, same greenness? Environmental literacy models integrated with teachers' environmental education practices for academic vs. technical/vocational high school students. *Cogent Education*, 11(1), 2357922. <https://doi.org/10.1080/2331186X.2024.2357922>
- Coman, C., Țiru, L. G., Meseșan-Schmitz, L., Stanciu, C., & Bularca, M. C. (2020). Online Teaching and Learning in Higher Education during the Coronavirus Pandemic: Students' Perspective. *Sustainability*, 12(24), 10367. <https://doi.org/10.3390/su122410367>
- Duncavage, E. J., Coleman, J. F., De Baca, M. E., Kadri, S., Leon, A., Routbort, M., Roy, S., Suarez, C. J., Vanderbilt, C., & Zook, J. M. (2023). Recommendations for the Use of in Silico Approaches for Next-Generation Sequencing Bioinformatic Pipeline Validation. *The Journal of Molecular Diagnostics*, 25(1), 3-16. <https://doi.org/10.1016/j.jmoldx.2022.09.007>
- Ginting, F. W., Mellyzar, M., & Lukman, I. R. (2023). Analysis of Student Environmental Literacy: PjBl-Based Learning that is Integrated STEM. *Jurnal Penelitian Pendidikan IPA*, 9(1), 242-248. <https://doi.org/10.29303/jppipa.v9i1.2599>
- Gostel, M. R., & Kress, W. J. (2022). The Expanding Role of DNA Barcodes: Indispensable Tools for Ecology, Evolution, and Conservation. *Diversity*, 14(3), 213. <https://doi.org/10.3390/d14030213>
- Haleem, A., Javaid, M., Qadri, M. A., & Suman, R. (2022). Understanding the role of digital technologies in education: A review. *Sustainable Operations and Computers*, 3, 275-285. <https://doi.org/10.1016/j.susoc.2022.05.004>
- Heather, J. M., & Chain, B. (2016). The sequence of sequencers: The history of sequencing DNA. *Genomics*, 107(1), 1-8. <https://doi.org/10.1016/j.ygeno.2015.11.003>
- Hyun, K.-A., Boo, K.-H., & Hyun, C.-G. (2025). Taxonomic Identification, Complete Genome Sequencing, and In Silico Genome Mining of the Actinobacterium *Lentzea* sp. JNUCC 0626 Isolated from Jeju Gotjawal. *Acta Microbiologica Hellenica*, 70(1), 8. <https://doi.org/10.3390/amh70010008>
- Jones, A. M. (2003). The use and abuse of PowerPoint in Teaching and Learning in the Life Sciences: A Personal Overview. *Bioscience Education*, 2(1), 1-13. <https://doi.org/10.3108/beej.2003.02000004>
- Kalendar, R., Shevtsov, A., Otarbay, Z., & Ismailova, A. (2024). In silico PCR analysis: A comprehensive bioinformatics tool for enhancing nucleic acid amplification assays. *Frontiers in Bioinformatics*, 4, 1464197. <https://doi.org/10.3389/fbinf.2024.1464197>
- Khairani, I., Saefudin, S., & Amprasto, A. (2023). Implementation of Biology Learning by Utilizing The Local Potential of The Citarum River to Increase Students' Environmental Literacy on Environmental Change Material. *Jurnal Penelitian Pendidikan IPA*, 9(8), 6157-6165. <https://doi.org/10.29303/jppipa.v9i8.3638>
- Kim, A.-Y., Lee, W.-S., & Son, Y. (2024). The Interaction between Climate Change and Biodiversity Can Be Assessed from a Material Cycle Perspective. *Diversity*, 16(8), 506. <https://doi.org/10.3390/d16080506>
- Krehenwinkel, H., Pomerantz, A., & Prost, S. (2019). Genetic Biomonitoring and Biodiversity Assessment Using Portable Sequencing Technologies: Current Uses and Future Directions. *Genes*, 10(11), 858. <https://doi.org/10.3390/genes10110858>
- Liu, S., Reynolds, B. L., Thomas, N., & Soyooof, A. (2024). The Use of Digital Technologies to Develop Young Children's Language and Literacy Skills: A

- Systematic Review. *Sage Open*, 14(1), 21582440241230850. <https://doi.org/10.1177/21582440241230850>
- Malamon, J. S. (2024). DNA N-gram analysis framework (DNAnamer): A generalized N-gram frequency analysis framework for the supervised classification of DNA sequences. *Heliyon*, 10(17), e36914. <https://doi.org/10.1016/j.heliyon.2024.e36914>
- Marques, L., Costa, B., Pereira, M., Silva, A., Santos, J., Saldanha, L., Silva, I., Magalhães, P., Schmidt, S., & Vale, N. (2024). Advancing Precision Medicine: A Review of Innovative In Silico Approaches for Drug Development, Clinical Pharmacology and Personalized Healthcare. *Pharmaceutics*, 16(3), 332. <https://doi.org/10.3390/pharmaceutics16030332>
- Mensah, J. (2019). Sustainable development: Meaning, history, principles, pillars, and implications for human action: Literature review. *Cogent Social Sciences*, 5(1), 1653531. <https://doi.org/10.1080/23311886.2019.1653531>
- Ming, L., Wang, Y., Liu, G., Meng, L., & Chen, X. (2024). Assessing the impact of human activities on ecosystem asset dynamics in the Yellow River Basin from 2001 to 2020. *Scientific Reports*, 14(1), 22227. <https://doi.org/10.1038/s41598-024-73121-4>
- Moses Adeleke Adeoye, Kadek Adrian Surya Indra Wirawan, Made Shania Satya Pradnyani, & Nyoman Intan Septiarini. (2024). Revolutionizing Education: Unleashing the Power of the ADDIE Model for Effective Teaching and Learning. *JPI (Jurnal Pendidikan Indonesia)*, 13(1), 202-209. <https://doi.org/10.23887/jpiundiksha.v13i1.68624>
- O'Reilly, C., Devitt, A., & Hayes, N. (2022). Critical thinking in the preschool classroom – A systematic literature review. *Thinking Skills and Creativity*, 46, 101110. <https://doi.org/10.1016/j.tsc.2022.101110>
- Pan, C.-T., & Hsu, S.-J. (2020). Effects of a One-day Environmental Education Program on Sixth-Graders' Environmental Literacy at a Nature Center in Eastern Taiwan. *Sustainability*, 12(12), 5043. <https://doi.org/10.3390/su12125043>
- Pantiwati, Y., Permana, F. H., Aminudin, A., Nurrohman, E., & Sari, T. N. I. (2024). Representation of the use of Media and Teaching Materials in Science Learning for Junior High School Students. *Jurnal Penelitian Pendidikan IPA*, 10(3), 1075-1082. <https://doi.org/10.29303/jppipa.v10i3.6168>
- Rubini, B., Pursitasari, I. D., Suriansyah, M. I., Ramadhanti, G. N., & Rachman, I. (2023). Improving Students' Eco-literacy through the Development of Electronic Interactive Teaching Materials on Climate Change. *Jurnal Penelitian Dan Pembelajaran IPA*, 9(2), 288. <https://doi.org/10.30870/jppi.v9i2.20051>
- Salvatore, C., & Wolbring, G. (2022). Coverage of Disabled People in Environmental-Education-Focused Academic Literature. *Sustainability*, 14(3), 1211. <https://doi.org/10.3390/su14031211>
- Şeker, M. (2023). A study on how environmental issues are discussed in social studies textbooks. *Environment, Development and Sustainability*, 26(8), 21325-21352. <https://doi.org/10.1007/s10668-023-03532-2>
- Theissinger, K., Fernandes, C., Formenti, G., Bista, I., Berg, P. R., Bleidorn, C., Bombarely, A., Crottini, A., Gallo, G. R., Godoy, J. A., Jentoft, S., Malukiewicz, J., Mouton, A., Oomen, R. A., Paez, S., Palsbøll, P. J., Pampoulie, C., Ruiz-López, M. J., Secomandi, S., & Zammit, G. (2023). How genomics can help biodiversity conservation. *Trends in Genetics*, 39(7), 545-559. <https://doi.org/10.1016/j.tig.2023.01.005>
- Valdez-Baez, J., Da Costa, F. M. R., Pinto Gomide, A. C., Profeta, R., Da Silva, A. L., Sousa, T. D. J., Viana, M. V. C., Bentes Kato, R., Americo, M. F., Dos Santos Freitas, A., Carvalho, R. D. D. O., Brenig, B., Martins, F. S., Aburjaile, F., & Azevedo, V. (2022). Comparative Genomics and In Silico Evaluation of Genes Related to the Probiotic Potential of *Bifidobacterium breve* 1101A. *Bacteria*, 1(3), 161-182. <https://doi.org/10.3390/bacteria1030013>
- Van De Pol, L., Van Der Biest, K., Taelman, S. E., De Luca Peña, L., Everaert, G., Hernandez, S., Culhane, F., Borja, A., Heymans, J. J., Van Hoey, G., Vanaverbeke, J., & Meire, P. (2023). Impacts of human activities on the supply of marine ecosystem services: A conceptual model for offshore wind farms to aid quantitative assessments. *Heliyon*, 9(3), e13589. <https://doi.org/10.1016/j.heliyon.2023.e13589>
- Vashisht, V., Vashisht, A., Mondal, A. K., Farmaha, J., Alptekin, A., Singh, H., Ahluwalia, P., Srinivas, A., & Kolhe, R. (2023). Genomics for Emerging Pathogen Identification and Monitoring: Prospects and Obstacles. *BioMedInformatics*, 3(4), 1145-1177. <https://doi.org/10.3390/biomedinformatics3040069>
- Wahyu, Y., Sadia, I. W., Suami, N. K., & Suastra, I. W. (2020). The Effect of science learning bases-STEM assisted by augmented reality toward scientific attitudes and science outcomes. *Journal of Physics: Conference Series*, 1567(4), 042015. <https://doi.org/10.1088/1742-6596/1567/4/042015>
- Weiskopf, S. R., Rubenstein, M. A., Crozier, L. G., Gaichas, S., Griffis, R., Halofsky, J. E., Hyde, K. J.

W., Morelli, T. L., Morissette, J. T., Muñoz, R. C., Pershing, A. J., Peterson, D. L., Poudel, R., Staudinger, M. D., Sutton-Grier, A. E., Thompson, L., Vose, J., Weltzin, J. F., & Whyte, K. P. (2020). Climate change effects on biodiversity, ecosystems, ecosystem services, and natural resource management in the United States. *Science of The Total Environment*, 733, 137782. <https://doi.org/10.1016/j.scitotenv.2020.137782>