JURNAL INOVASI TEKNOLOGI PENDIDIKAN

Jurnal Inovasi Teknologi Pendidikan
Volume 13, No. 2, June 2026 (184-193)
Online: http://journal.uny.ac.id/index.php/jitp

IPTPI Ikatan Profesi Teknologi Pendidikan Indonesia
APS-TPI

Designing ecobalance: A web-based learning product for enhancing climate change literacy and environmental awareness

Nofita Ikayanti*, Ratna Komala, Diana Vivanti Sigit
Universitas Negeri Jakarta, Indonesia.
***** Corresponding Author. E-mail: nofitaikayanti@gmail.com

ARTICLE INFO

Article History
Received:
25 December 2025;
Revised:
18 June 2026;
Accepted:
18 June 2026;
Available online:
30 June 2026.

Keywords
Climate change;
Ecobalance website;
Environmental awareness

ABSTRACT

Climate change is one of the most pressing global challenges affecting human life. Therefore, students need climate change literacy and environmental awareness to support environmental sustainability. This study aimed to develop the Ecobalance website as a learning medium to enhance both competencies. The research employed the Educational Design Research (EDR) approach using the ADDIE model, consisting of the Analysis, Design, Development, Implementation, and Evaluation stages. The participants were 60 tenth-grade students, including 30 students in the experimental class and 30 in the control class, selected through purposive sampling. Data were collected using questionnaires and tests. The Ecobalance website achieved feasibility scores of 90.1%, 90.63%, and 86.67% from material experts, media experts, and students, respectively, indicating that it was "Very Feasible." The implementation produced N-gain scores of 70.95% for climate change literacy and 62.54% for environmental awareness, demonstrating its effectiveness compared with conventional learning. These findings indicate that the Ecobalance website is an effective digital learning medium for environmental education. Future research should examine its long-term impact on students' environmental behavior and evaluate its implementation across different educational levels and learning contexts to assess its broader effectiveness and scalability.

How to cite:
Ikayanti, N., Komala, R., & Sigit, D. V. (2026). Designing Ecobalance: A web-based learning product for enhancing climate change literacy and environmental awareness. *Jurnal Inovasi Teknologi Pendidikan, 13*(1), 184-193. https://doi.org/10.21831/jitp.v13i2.94066

INTRODUCTION

The rapid growth of the global population has intensified anthropogenic activities that contribute significantly to greenhouse gas emissions and global climate change (Sagena et al., 2022; Setiani, 2020). Climate change has become a critical global issue due to its extensive impacts on environmental sustainability and human life (Winarno, 2019). In response to this challenge, students hold strategic potential as agents of change in promoting pro-environmental behavior through education (Tareze et al., 2022). However, several studies indicate that students' environmental awareness remains at a relatively low level, as many have not been actively involved in concrete environmental actions despite having basic environmental knowledge and attitudes (Moody-Marshall, 2023; Habibah & Irawan, 2023; Aisyah et al., 2024).

Iin addition to environmental awareness, climate change literacy is an essential competency for encouraging meaningful action toward sustainability (Haidar et al., 2023). Climate literacy

encompasses understanding the causes, impacts, and mitigation strategies of climate change (Supratiningsih et al., 2023). Nevertheless, students' climate literacy in several regions remains at a basic level, with limited ability to connect global climate issues to local contexts (Haidar et al., 2023). Needs analysis further indicates that a significant proportion of students have limited exposure to reliable climate information and mostly rely on social media as their main source. This condition highlights the urgent need for innovative learning media that can support authentic, contextual, and action-oriented learning experiences (Luthfia, 2019).

Web-based learning media offer strong potential to enhance students' independent learning and literacy engagement through interactive and accessible features (Dimyati et al., 2024; Hekmah et al., 2019). However, most learning practices still rely on conventional, one-way instructional media. To address this gap, this study develops the Ecobalance website, a project-based digital learning platform that integrates climate change education and environmental awareness, complemented by a recycle market feature to encourage real-world environmental action. Previous studies have demonstrated the effectiveness of technology-based learning media in improving students' learning outcomes. Fitriyah et al., (2021) developed learning media using the ADDIE model and reported that the product achieved high feasibility based on expert validation and student responses. Likewise, Meryantie et al., (2025) found that technology-supported learning effectively enhanced students' eco-literacy through meaningful learning experiences. In addition, Kumar et al., (2023) reported that web-based climate change education significantly improved students' climate change literacy.

However, these studies mainly focused on either digital learning media development, climate change literacy, or environmental literacy separately. Few studies have integrated climate change literacy and environmental awareness into a single interactive web-based learning platform for senior high school students. Therefore, this study contributes to the field of environmental education by developing and evaluating the Ecobalance website using the Educational Design Research (EDR) approach. The study provides an empirically validated web-based learning model that integrates climate change literacy and environmental awareness, and demonstrates its effectiveness in improving students' learning outcomes. In addition, this study is expected to contribute to the development of innovative digital learning design that can be adapted in other environmental education contexts. Furthermore, the findings may serve as a reference for educators in integrating technology-based learning with sustainability-oriented competencies in secondary education.

METHOD

This study employed an AI research and development (R&D) approach using the Educational Design Research (EDR) framework with the ADDIE model, which consists of five stages: analyze, design, development, implementation, and evaluation (Branch, 2009). The product developed in this study was a project-based learning website named Ecobalance, designed as an alternative digital learning medium for climate change topics. The research was conducted from January to May 2025 at Islamic Village Private High School, Tangerang Regency, Banten Province, Indonesia. The research participants consisted of 60 tenth-grade students, two biology teachers, and three experts, including an AI media expert, an AI subject matter expert, and an AI language expert for product validation purposes. The school was selected using purposive sampling, while the experimental and control classes were determined using simple random sampling. Class X.2 was assigned as the experimental group and class X.3 as the control group, with each class consisting of 30 students based on the Slovin formula calculation. The effectiveness of the product was tested using a control group pretest–posttest experimental design. Both groups were given a pretest before the implementation of the learning treatment and a posttest after the treatment. The experimental group received learning using the Ecobalance website integrated with the project-based learning model, while the control group was taught using PowerPoint media with the problem-based learning model. The dependent variables in this study were students' climate change literacy and environmental awareness. This study employed the Educational Design Research (EDR) approach with the ADDIE development model to systematically develop and evaluate the Ecobalance website. The research

process followed five main stages: analysis, design, development, implementation, and evaluation. The overall procedure is illustrated in the following flowchart Figure1.

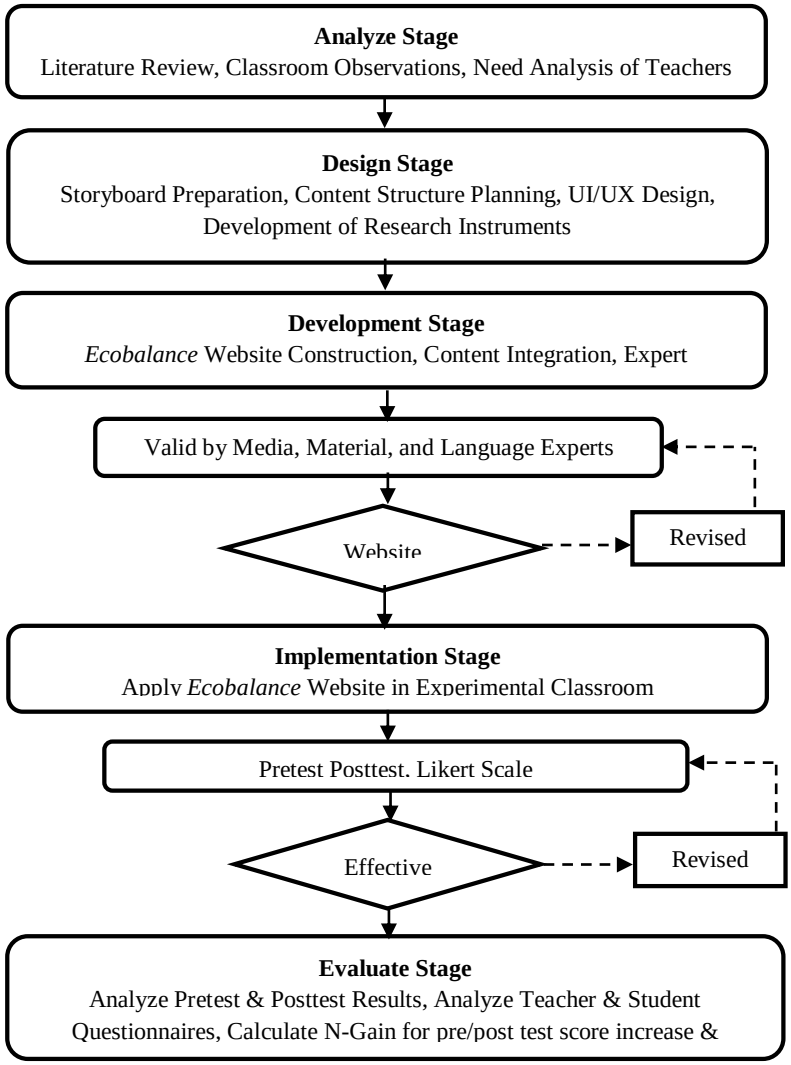

Figure 1. ADDIE Model Procedure Flowchart

Based on the research procedure shown in the flowchart, several data collection instruments were developed and used to gather information at each stage of the study, including analysis, development, implementation, and evaluation. The details of the data collection instruments are presented in the following Table 1.

Table 1. Data Collection Instruments

No.	Technique	Instrument	Assessment Criteria
1	Need Analyze	Questionnaire	Students' and teachers' perceptions of learning and learning media
2	Learning Material Feasibility	Material expert questionnaire	Content suitability and presentation feasibility
		Media expert questionnaire	Language components, visual design, and presentation quality
		Teacher and student questionnaire	Content quality, design, usefulness, and product effectiveness
3	Instrument Feasibility for Climate Change Literacy and	Climate change literacy test and environmental awareness questionnaire	Validity and reliability testing

No.	Technique	Instrument	Assessment Criteria
	Environmental Awareness		
4	Learning Media Implementation Results	Pretest and posttest instruments	Descriptive analysis, assumption testing, and effectiveness testing (N-gain)
5	Student and Teacher Responses	Questionnaire	User responses toward product use

To ensure the quality of the research instruments, validity and reliability testing were conducted on the instruments used to measure climate change literacy and environmental awareness. The results of the validity and reliability analysis are presented in the following Table 2.

Table 2. Instrument Validation Result

No.	Environmental Awareness Instrument			Climate Change Literacy Instrument		
	Indicator	**Item Number Validity**	**Reliability**	**Indicator**	**Item Number Validity**	**Reliability**
1	Cognitive	1,2,3,4,5, 6*,7*,8	Cronbach's Alpha 0.927 ≥ 0.6 (Reliable)	Knowledge about climate change	2*,4*,6,18, 19,25,28*	Cronbach's Alpha 0.927 ≥ 0.6 (Reliable)
2	Affective	9,10,11,12, 13*,14,15		Understanding about impacts and threats of climate change	1,3*,7,9, 10,20,21*, 22,23,24,29	
3	Conative	16,17,18*, 19,20,21, 22*,23,24		Motivation to make accurate decisions to implement mitigation and adaptive solutions to the climate crisis	5*,8*,11, 12,13,14,15, 16,17,26, 27,30	
4	Active	25,26,27 28,29,30				

Note (*): Invalid Instrument

Based on the results of the validity and reliability testing, the research instruments were considered appropriate for use in data collection. Therefore, the validated instruments were subsequently implemented in the experimental phase to examine the effectiveness of the Ecobalance website in improving students' climate change literacy and environmental awareness. The results of the implementation are presented and discussed in the following section.

RESULTS AND DISCUSSION

Results

The results of the Ecobalance website development are presented according to the five stages of the ADDIE model. At the analysis stage, a needs assessment was conducted involving 50 eleventh-grade students and three biology teachers. The findings revealed that 57% of students considered climate change material to be very important, and none perceived it as unimportant, indicating a high level of awareness of its relevance. However, only 14% of students reported having a strong understanding of the causes and impacts of climate change, and 82% were not actively involved in environmental action. In terms of learning media, 78% of students stated that PowerPoint was the most frequently used medium, while only 2% reported the use of websites. Most students relied on social media as their main source of climate information (58%), although 26% accessed credible

environmental organization websites. Moreover, 60% of students strongly expected the Ecobalance website to support their learning. Teachers unanimously (100%) agreed on the importance of climate change education, yet 66.7% reported that students' engagement and understanding remained low. Teachers also emphasized the need for visually attractive, content-rich, and context-based digital learning media. These findings confirmed the urgency of developing a project-based digital learning platform to improve climate change literacy and environmental awareness. The results of the needs analysis can be seen in Table 3.

Table 3. Needs Assessment Results

No.	Indicator	Response Category	Percentage (%)
1	Importance of climate change topic	Very Important	57%
		Other Responses	43%
2	Understanding of climate change topic	Less Understanding	14%
		Good Understanding	86%
3	Involvement in environmental change actions	Less Involved	82%
		Very Involved	12%
4	Learning media frequently used by teachers for climate change issues	Website	2%
		Other Media	98%
5	Need for the Ecobalance website to support climate change	Very Important	60%
		Other Responses	40%

At the design stage, the Ecobalance website was systematically planned based on the needs analysis results. The instructional design was aligned with the Project-Based Learning (PjBL) model to promote context- and action-oriented learning. The website structure was conceptualized through storyboards, learning flow design, and navigation mapping. Four main features were designed: EcoInfo for climate information and news, EcoProject for weekly environmental action projects, EcoShop for marketing recycled student products, and EcoQuiz for evaluation. At this stage, research instruments were also developed and validated. The climate change literacy instrument consisted of 20 two-tier multiple-choice items, while the environmental awareness instrument consisted of 25 Likert-scale statements. Validity testing showed that several items were excluded due to low significance values, while reliability testing using Cronbach's Alpha showed excellent reliability coefficients of 0.908 for climate literacy and 0.927 for environmental awareness. The display of the EcoInfo, EcoProject, EcoShop, and EcoQuiz features can be seen in Figure 2.

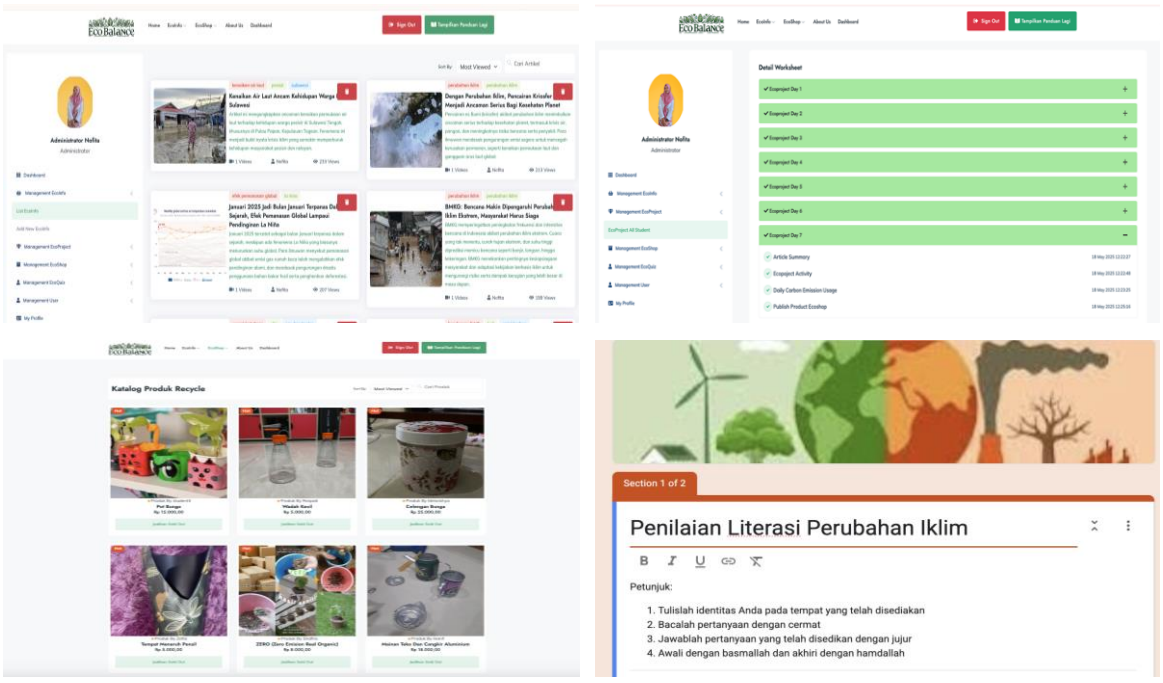

Figure 2. EcoInfo, EcoProject, EcoShop, and EcoQuiz Feature Display

At the development Stage, the Ecobalance website was fully constructed using web programming technologies and online server hosting. All designed features were implemented according to the PBL syntax. Expert validation was conducted involving media experts, subject matter experts, and language experts. The material expert validation yielded an average feasibility score of 90.1%, categorized as "very feasible". Media expert validation resulted in a score of 90.63%, also categorized as "very feasible". The expert validation results are shown in Table 4.

Table 4. Expert Validation Result

No.	Material Expert Validation			Learning Media Expert Validation		
	Indicator	**Average**	**Description**	**Indicator**	**Average**	**Description**
1	Material Substance	93.7	Very Feasible	Language	87.5	Very Feasible
2	Material Presentation	97.5	Very Feasible	Visual Display	92.2	Very Feasible
3	Learning Design	85.4	Very Feasible	Overall Display	92.5	Very Feasible
4	Media Effects on Learning	93.7	Very Feasible			
Score (%)		**90.1**	**Very Feasible**	**Score (%)**	**90.63**	**Very Feasible**

During the development phase, product trials were conducted involving biology teachers and students. The trial with biology teachers resulted in a feasibility score of 93%, indicating a very high level of suitability. Meanwhile, a small-group trial involving 15 students yielded an average score of 86.67%, reflecting excellent usability and perceived learning benefits. Revisions were implemented based on feedback from experts and users, focusing on improving the clarity of learning objectives, enriching the content, enhancing visual representation, and refining usability guidelines. The results of the product trials with biology teachers and students are presented in Table 5.

Table 5. Biology Teachers & Students Assessment Results

No.	Biology Teachers Assessment			Students Assessment		
	Indicator	**Average**	**Description**	**Indicator**	**Average**	**Descripti on**
1	Ease of Understanding	96.9	Very Feasible	Understanding the Material	88.67	Very Feasible
2	Product Usage	87.5	Very Feasible	Product Usage	87.89	Very Feasible
3	Product Appearance	100	Very Feasible	Product Appearance	84.38	Very Feasible
4	Product Benefits	87.5	Very Feasible	Product Benefits	85.42	Very Feasible
Score (%)		**93**	**Very Feasible**	**Score (%)**	**86.67**	**Very Feasible**

At the implementation stage, the Ecobalance website was applied in an experimental class consisting of 30 tenth-grade students, while another 30 students in a control class learned using PowerPoint-based instruction. Both classes completed pretests and posttests measuring climate change literacy and environmental awareness. Descriptive analysis processed using SPSS showed substantial improvements in the experimental group compared to the control group. The mean literacy score of the experimental class increased from 58.33 to 88.87, while the control group improved from 60.60 to 77.70. The N-gain for the experimental group reached 70.95%, categorized as moderately effective, compared to 41.02% in the control group. Environmental awareness scores also showed a greater improvement in the experimental class, with posttest scores reaching 92.17 compared to 85.70 in the control group. The descriptive test results are presented in Table 6.

Table 6. The Descriptive Test Results

No.	Analysis	Class Category	Climate Change Literacy		Environmental Awareness	
			Pretest	**Posttest**	**Pretest**	**Posttest**
1	Number of Samples	Experiment	30	30	30	30
		Control	30	30	30	30
2	Mean	Experiment	58.33	88.87	78.97	92.17
		Control	60.60	77.70	74.60	85.70
3	Standard Deviation	Experiment	10.58	5.11	4.57	4.3
		Control	8.57	4.96	4.63	3.58
4	Lowest Value	Experiment	38	80	70	82

No.	Analysis	Class Category	Climate Change Literacy		Environmental Awareness	
			Pretest	Posttest	Pretest	Posttest
		Control	48	65	65	74
5	Highest Value	Experiment	78	98	90	98
		Control	75	90	81	92
6	Variant	Experiment	111.95	26.18	20.93	18.55
		Control	73.55	24.63	21.49	14.83
7	N-gain	Experiment	70.95%		62.54%	
		Control	41.02%		42.12%	

At the final evaluation stage, summative evaluation was conducted based on the entire development, validation, and implementation process. The results demonstrated that the Ecobailaince website met the criteria of a highly feasible, effective, and pedagogically appropriate digital learning medium. Final refinements included improving visual appearance, optimizing interactive features, and distributing direct access links to teachers and students. Overall, the Ecobalance website proved to be a valid and effective project-based digital learning innovation for enhancing climate change literacy and environmental awareness among senior high school students.

Discussion

This study employed the ADDIE instructional design model (Analysis, Design, Development, Implementation, and Evaluation) to guide the systematic development of the Ecobalance website for climate change education. The ADDIE model has been widely applied in educational media development due to its structured yet flexible nature, enabling continuous refinement based on learner needs and formative feedback (Branch, 2009). Previous studies confirm that AI-based digital learning designs contribute to improved learning engagement and conceptual understanding when each phase is implemented iteratively and coherently (Dilaines et al., 2024). The needs analysis revealed a clear gap between students' learning preferences and instructional practices in schools. While most students perceived climate change as a highly important topic, they primarily accessed related information through social media platforms. In contrast, teachers relied predominantly on textbooks and static presentation media. This discrepancy aligns with findings by Moriska & Hanif (2024), who reported that teacher-centered use of conventional media limits students' active engagement and critical processing of environmental issues. Moreover, reliance on social media as an information source has been associated with increased exposure to misinformation and fragmented scientific understanding, particularly in climate-related topics (Berger et al., 2023; Essien et al., 2025). These findings highlight the need for an instructional intervention that integrates accessible digital media with scientifically validated content.

Based on the analysis results, the learning design was structured around Project-Based Learning (PjBL), supported by reliable assessment instruments for climate change literacy and environmental awareness. PjBL has been widely recognized as an effective approach for environmental education because it engages learners in authentic problem-solving and contextualized learning experiences (Lopes & Palacios, 2024). The instruments developed in this study demonstrated excellent internal consistency, with Cronbach's alpha values exceeding 0.90, indicating strong reliability. Such reliability levels are consistent with standards in educational measurement, where alpha values above 0.70 indicate acceptable reliability and values above 0.90 reflect excellent consistency (Taber, 2016; Singh, 2024). Additionally, the use of two-tier diagnostic items strengthened the measurement of climate literacy by capturing both conceptual understanding and potential misconceptions, as recommended in science education research (Taber, 2024). During the development phase, the Ecobalance website was constructed by integrating multimedia learning materials, interactive quizzes, and project-based environmental activities. Expert validation results from both content and media specialists indicated that the website met high feasibility standards, with average scores above 90%. Similar validation outcomes have been reported in previous studies, where digital learning media achieving feasibility scores above 85% were categorized as highly valid and ready for classroom use (Devi & Rusdinal, 2023; Mahmuzah et al., 2024). Limited trials involving biology teachers and small groups of students further demonstrated that the website was practical, easy to use, and pedagogically appropriate. These findings support earlier research by Irfan

et al., (2024), which emphasized the importance of iterative trials in improving the usability and effectiveness of digital learning media.

The implementation of the Ecobalance website in the experimental class resulted in higher descriptive gains in both climate change literacy and environmental awareness compared to the control class. Based on pretest and posttest results, the experimental group achieved N-gain values of 70.95% for climate change literacy and 62.54% for environmental awareness, both categorized as moderately effective. In contrast, the control group showed lower N-gain values, indicating less substantial improvement. These results are consistent with previous studies demonstrating that project-based digital learning environments yield higher learning gains than conventional instruction, particularly in sustainability-related topics (Anggraini et al., 2022). The descriptive analysis of indicator-level improvements showed that students in the experimental group experienced notable gains not only in cognitive aspects but also in affective and cognitive dimensions of environmental awareness. The greatest improvement was observed in the cognitive dimension, suggesting that students were more inclined to engage in pro-environmental actions after participating in project-based activities through the Ecobalance platform. This finding aligns with Bramwell-Lalor et al., (2020), who reported that experiential and project-based environmental learning effectively fosters behavioral intentions and real-world environmental action. Overall, the evaluation results indicate that the Ecobalance website successfully supports meaningful learning by integrating scientific literacy, emotional engagement, and action-oriented environmental education.

CONCLUSION

This study concludes that the Ecobalance website developed through the ADDIE model and implemented using a project-based learning approach is valid, feasible, and effective in improving students' climate change literacy and environmental awareness at the senior high school level. The findings consistently show that students who learned using Ecobalance achieved significantly higher gains in both literacy and environmental awareness compared to those who learned through conventional problem-based PowerPoint media, as supported by descriptive analysis with N-gain scores. These results confirm that integrating digital learning media with real-world environmental action through project-based learning can strengthen students' conceptual understanding, attitudes, and behavioral intentions toward climate change issues. Based on these findings, the Ecobalance website can be operationally implemented as an alternative instructional medium in climate change learning to support interactive, contextual, and action-oriented science education. Teachers are encouraged to use Ecobalance to facilitate student projects related to carbon footprint reduction and environmental campaigns, while schools may adopt it as part of sustainable education programs. Furthermore, future research is recommended to investigate the long-term impact of the Ecobalance website on students' climate change literacy, environmental awareness, and pro-environmental behaviors. Future studies may also integrate advanced interactive features, such as gamification, personalized learning pathways, and adaptive feedback, and evaluate their effectiveness across different schools and educational levels.

ACKNOWLEDGEMENT

The author would like to express sincere gratitude to the research supervisors, Prof. Dr. Ratna Komala, M.Si., and Prof. Dr. Diana Vivanti Sigit, M.Si., for their valuable guidance throughout this study. Appreciation is also extended to Dr. Hanum Isfaeni, M.Si., and Dr. Rizhal Hendi Ristanto, M.Pd., for their constructive feedback as examiners. The author thanks the lecturers of the Biology Education Program, Universitas Negeri Yogyakarta, for their academic support. Special thanks are addressed to Farida Susantina, M.Pd., and Nunung Iswatun Chasanah, M.Si., for their expertise in validating the developed product. Gratitude is also extended to the principal, teachers, and students of Islamic Village Private High School for their cooperation and participation in this research. The author also acknowledges the support from family and colleagues who contributed to the completion of this research.

REFERENCES

Aisyah, A., Putri, K. A. J. A., & Firjanah, L. (2024). Pentingnya membangun kesadaran lingkungan melalui pembelajaran PKN di sekolah dasar guna membentuk karakter peduli lingkungan pada siswa. *Jurnal Pendidikan Guru Sekolah Dasar*, *1*(3), 11-20. https://doi.org/10.47134/pgsd.v1i3.529

Anggraini, D., Abdurrahman, & Herlina, K. (2022). Development of learning program based on multiple representations integrated with PJBL George Lucas and STEM to foster students' sustainability literacy. *Jurnal Pendidikan Fisika dan Keilmuan*, *8*(2), 253–279. https://doi.org/10.25273/jpfk.v8i2.15660

Berger, L., Marie, L., Anna, K., Felix, M., & Johannes, M. (2023). Debunking "Fake News" on social media: Short-term and longer-term effects of fact-checking and media literacy interventions. *ECON tribute Discussion*, Paper No. 262. https://share.google/xuSseBGhfV2cGhowP

Bramwell-Lalor, S., Kelly, K., Ferguson, T., Gentles, C. H., & Roofe, C. (2020). Project-based learning for environmental sustainability action. *Southern African Journal of Environmental Education*, *36*(1), 57-71. https://doi.org/10.4314/sajee.v36i1.10

Branch, R. M. (2009). *Instructional design*. In Digital Learning: The Key Concepts. Springer International Publishing. https://doi.org/10.4324/9780429425240-105

Devi, M. Y., & Rusdinal. (2023). Validation of digital learning media to improve the basic literacy skills of low-grade elementary school students. *Jurnal Obsesi: Jurnal Pendidikan Anak Usia Dini*, *7(*1), 119–129. https://doi.org/10.31004/obsesi.v7i1.3713

Dilaines, L. E., Astuti, E., & Yusdita, E. E. (2024). Improving student learning outcomes through accurate online modules with the ADDIE model. *Journal of Education Technology*, *8*(2), 275–286. https://doi.org/10.23887/jet.v8i2.67576

Dimyati, M., Karim, J., Jabbar, A., Amrulloh, A., Irfani, M., & Budi, S. (2024). Desain dan implementasi platform edukasi berbasis website menggunakan extreme programming. *Jurnal Sistem dan Teknologi Informas*i, *12*(3), 461-470. https://doi.org/10.26418/justin.v12i3.77402

Essien, E. O. (2025). Climate change disinformation on social media: A meta-synthesis on epistemic welfare in the post-truth era. *Soc. Sci*, *14*(5), 1-34. https://doi.org/10.3390/socsci14050304

Fitriyah, I., Wiyokusumo, I., & Leksono, I. P. (2021). Pengembangan media pembelajaran Prezi dengan model ADDIE, simulasi dan komunikasi digital. *Jurnal Inovasi Teknologi Pendidikan*, *8*(1), 84–97. https://doi.org/10.21831/jitp.v8i1.42221

Habibah, M., & Irawan, F. A. (2023). Tingkat kesadaran lingkungan siswa dalam menghadapi pemanasan global dalam kegiatan literasi bumiku program kampus mengajar 4. *Jurnal Pendidikan Geosfer*, *8*(1), 17–28. https://doi.org/10.24815/jpg.v8i1.29167

Haidar, D. A., Prastiti, T. D., Novianti, I., Wahyuningrum, E., Dafik, D., & Ridlo, Z. R. (2023). Aktivitas pembelajaran RBL dengan pendekatan STEAM: Pemanfaatan toples kaca bekas dalam pengembangan terarium dengan konsep keseimbangan ekosistem berbantuan games simulasi untuk meningkatkan literasi perubahan iklim. *In Ebook CGANT Universitas Jember* 113–140. https://www.scribd.com/document/736242672/30-140-1-PB

Hekmah, N., Wilujeng, I., & Suryadarma, I. G. P. (2019). Web-lembar kerja siswa IPA terintegrasi lingkungan untuk meningkatkan literasi lingkungan siswa. *Journal Innovations in Pedagogy*, *5*(2), 129–138. https://doi.org/10.21831/jipi.v5i2.25402

Irfan, Febriati, F., Mawarni, S., & Hakim, A. (2024). Enhancing higher education through interactive microlearning e-modules. *Indonesian Journal of Educational Technology*, *3*(1), 1–9. https://doi.org/10.26858/ijet.v3i1.2180

Kumar, P., Sahani, J., Rawat, N., Debele, S., Tiwari, A., Emygdio, A.P.M., Abhijith, K.V., Kukadia, V., Holmes, K., Pfautsch, S. (2023). Using empirical science education in schools to improve climate change literacy. *Renewable and Sustainable Energy Reviews*, *178*(1), 1-13. https://doi.org/10.1016/j.rser.2023.113232

Luthfia, A. R. (2019). Penguatan literasi perubahan iklim di kalangan remaja. *Jurnal Abadimas Adi Buana*, *3*(1), 39–42. https://doi.org/10.36456/abadimas.v3.i1.a1941

Lopes, J. A., & Palacios, F. J. P. (2024). Effects of AI project-based learning methodology on environmental awareness of secondary school students. *International Journal of Instruction*, *17*(1), 1–22. https://e-iji.net/ats/index.php/pub/article/view/492

Mahmuzah, R., Zahara, Y., Ningtiyas, F. A., Sinaga, N. A., Saragih, N. J., & Aufa, Z. Y. (2024). Analisis validitas media pembelajaran interaktif berbasis Android terintegrasi Smart Apps Creator bermuatan literasi numerasi. *Journal of Scientific Information and Educational Creativity*, *25*(2), 332–343. https://doi.org/10.30649/fisheries.v2i2.43

Meryantie, A., Huda, N., Tobing, V. M. T. L., & Muhajir. (2025). Implementation of TBL with constructivist and discovery learning approaches to enhance eco-literacy of homeschooling students. *Jurnal Inovasi Teknologi Pendidikan*, *12*(3), 307–316. https://doi.org/10.21831/jitp.v12i3.85855

Moody-Marshall, R. (2023). An investigation of environmental awareness and practice among a sample of undergraduate students in Belize. *Environmental Education Research*, *29*(7), 911–928. https://doi.org/10.1080/13504622.2022.2079613

Moriska, A., & Hanif, M. (2024). Interactive learning multimedia articulate storyline is an alternative medium to improve elementary students' critical thinking skills. *Journal Ilmiah Sekolah Dasar*, *8*(2), 258–269. https://doi.org/10.23887/jisd.v8i2.65310

Sagena, U. W., Panjaitan, O., Azizsyah, S. N., Hasyim, M., Dino, Mohd., & Sharifuddin, K. (2022). SDGs class for kids: edukasi kesadaran energi dan lingkungan kepada pelajar di kawasan IKN Nusantara. *Seminar Nasional Pengabdian Kepada Masyarakat*, 851–858. https://www.researchgate.net/publication/371349726_SDGs_Class_for_Kids_Edukasi_Kesadaran_Energi_dan_Lingkungan_Kepada_Pelajar_di_Kawasan_IKN_Nusantara

Setiani, P. (2020). *Sains perubahan iklim*. Bumi Aksara.

Singh, T. (2024). Reliability in student assessment: Implications for competency-based curriculum. *Indian Journal of Health Sciences and Biomedical Research (KLEU)*, *17*(2), 95-99. https://doi.org/10.4103/kleuhsj.kleuhsj_15_24

Supratiningsih, Dafik, I. H., Agustin, R., Nisviasari, I. L., Mursyidah., & Prihandini, R. M. (2023). Aktifitas pembelajaran RBL dengan pendekatan STEAM memanfaatkan waste paper dalam pembuatan miniatur organ jantung manusia berbantuan Augmented Reality (AR) dalam meningkatkan literasi perubahan iklim siswa. *Pengembangan Literasi Perubahan Iklim Berbasis Machine Learning dengan RBL-STEM*, (pp. 23–42). https://ebook-cgantunej.my.id/index.php/cgant/article/download/24/49

Taber, K. S. (2016). The use of Cronbach's Alpha when developing and reporting research instruments in science education. *Res Sci Educ*, *48*, 1273–1296 https://doi.org/10.1007/s11165-016-9602-2

Tareze, M., Indri Astuti, & Afandi. (2022). Model pembelajaran kolaborasi SDGs dalam pendidikan formal sebagai pengenalan isu global untuk meningkatkan kesadaran sosial peserta didik. *Visipena*, *13*(1), 42–53. https://doi.org/10.46244/visipena.v13i1.1978

Winarno, B. (2019). *Dinamika politik global kontemporer: Teori, aktor, isu dan analisis studi kasus*. Media Pressindo.