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Implementing Research-Based Learning Integrated with STEM to Foster Students' Climate Change Literacy through Creative Packaging Prototyping

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Abstract

Climate change education requires classroom experiences that move beyond the transmission of environmental facts and engage students in inquiry, design, data interpretation, and action-oriented problem solving. This study reports the implementation of Research-Based Learning integrated with STEM to foster secondary students' climate change literacy through creative packaging prototyping. The instructional design was developed from a broader learning-tool development project and implemented using recycled cardboard, Teachable Machine, and robotics to construct a prototype of an intelligent packaging production track for classifying limes as a local agricultural product. The study employed a developmental approach followed by classroom implementation using a nonequivalent control group design. Learning activities were organised around problem identification, information gathering, technological exploration, engineering design, mathematical analysis, and reporting. The findings indicate that the RBL–STEM design successfully embedded science, technology, engineering, and mathematics within a contextual sustainability task and created meaningful opportunities for students to examine climate-related issues, reuse inorganic waste, discuss carbon footprint reduction, analyse classification data, and communicate findings collaboratively. The study also developed a multidimensional climate change literacy framework encompassing conceptual understanding, causes, impacts, inquiry, communication, and solutions. Overall, the article suggests that research-based STEM learning offers a feasible and pedagogically meaningful pathway for strengthening climate change literacy through interdisciplinary and prototype-based classroom practice.

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INTRODUCTION

Climate change is not only an environmental issue but also an educational one. Schools are increasingly expected to help learners understand climate-related risks, interpret evidence, and develop the knowledge, skills, values, and attitudes needed to respond responsibly to environmental change. UNESCO has emphasized that climate change education should empower learners to act, while recent global reporting has argued that educational responses to climate change must go beyond knowledge transmission and move toward action-oriented learning for people and planet (Unesco, 2024; UNESCO, n.d.). This broader view positions climate education not as an optional enrichment topic, but as a core dimension of meaningful schooling in the twenty-first century.

The urgency of this agenda is reinforced by the growing impact of climate-related disruption on education itself. UNICEF reported that at least 242 million students in 85 countries or territories experienced school disruption due to climate-related hazards in 2024, underscoring that climate change now directly affects educational access, continuity, and student well-being (UNICEF, 2025). In this context, schools are not merely places where climate change is discussed conceptually; they are also institutions that must prepare students to interpret and respond to its real-world consequences.

Despite this urgency, climate change education often remains weakly integrated into formal schooling. In the Indonesian context, Tang (2024) found persistent incongruence between climate policy and education policy, along with limited integration of climate change education in formal educational practice. Such findings suggest that schools require practical and pedagogically sound models that can translate broad sustainability goals into everyday classroom activities. The challenge is therefore not only curricular, but also pedagogical: teachers need feasible ways to connect climate issues with subject learning, student inquiry, and classroom products.

The research report underlying this article identifies a similar need. It highlights the importance of strengthening students' literacy regarding climate change while simultaneously supporting teachers in designing learning that is creative, contextual, and environmentally relevant. In the original project, this need was addressed through a research-based STEM learning design involving recycled cardboard, digital classification tools, and robotics. For article purposes, the most coherent and publishable contribution lies in the implementation of the classroom model and its implications for students' climate change literacy.

One promising pedagogical response to this challenge is Research-Based Learning. RBL emphasizes investigation, interpretation, evidence use, and reporting, allowing students to learn through inquiry rather than passive reception. Thiem et al. (2023) found that research-based learning positively affected students' self-rated research competences, especially in reviewing prior knowledge, methodological thinking, reflection, and communication. Although much of the RBL literature has emerged from higher education, its core logic is relevant to school classrooms: students can be positioned as inquirers who identify problems, gather information, analyse findings, and communicate conclusions.

The integration of STEM further strengthens this orientation because climate change is inherently interdisciplinary. Climate literacy requires not only conceptual understanding, but also the ability to interpret data, evaluate problems, consider solutions, and act in relation to environmental issues. Kumar et al. (2023) showed that empirical science education can improve climate change literacy in school settings, while Leve et al. (2023) argued that implementing climate literacy in schools depends substantially on how teachers are prepared to teach it. Research has also shown that climate literacy is shaped by broader educational and behavioural processes, including pedagogy, evidence use, and student engagement with applied environmental problems (Pan et al., 2023).

The present study responds to this need by implementing an RBL–STEM learning design centred on a contextual sustainability task. Students were asked to use recycled cardboard, Teachable Machine, and robotics to create a prototype of an intelligent packaging production track for classifying limes. In this design, cardboard reuse was positioned as a response to the accumulation of inorganic packaging waste, while limes were introduced as a local alternative to imported lemons, allowing students to discuss local agriculture, carbon footprint reduction, and sustainability in a concrete way. These design choices are pedagogically important because they anchor climate-related learning in familiar materials and local practices rather than in abstract environmental discourse alone.

This contextual orientation is consistent with recent sustainability-oriented STEM work. Karakuyu & Karafil (2026) reported that recycling-based STEM education positively influenced secondary students' STEAM attitudes, recycling-related behaviours, and design thinking skills. Similarly, Cordaro et al. (2025) noted the importance of bridging STEM education and sustainability through meaningful educational practice. Together, such studies support the view that sustainability learning becomes more powerful when students engage with authentic environmental tasks, recycled materials, and interdisciplinary reasoning.

Based on this rationale, the purpose of this article is to present the implementation of a research-based STEM learning model and to discuss how it may foster students' climate change literacy through creative packaging prototyping. The article focuses on the instructional design, classroom implementation, literacy framework, and pedagogical implications of integrating recycled materials, simple machine-learning tools, and robotics into climate-responsive classroom learning.

METHOD

Research Design

This study employed a developmental research design followed by classroom implementation and quasi-experimental testing. In the development phase, the instructional tools were prepared using the 4-D model consisting of define, design, development, and disseminate. In the implementation phase, the developed tools were applied in classroom learning using a nonequivalent control group design. This combined approach was selected because the study aimed both to produce a contextual instructional model and to examine its use in classroom practice.

Focus of the Article Version

The broader research report originally included teacher creativity and teacher mentoring as part of the project agenda. In the article version, however, the focus is narrowed to the most coherent classroom-based contribution: the implementation of Research-Based Learning integrated with STEM to foster students' climate change literacy. This narrowing is methodologically appropriate because the report most clearly documents the learning syntax, the prototype task, the literacy indicators, and the student learning process.

Experimental Design

The classroom implementation used a nonequivalent control group design. The experimental group received instruction using the developed RBL–STEM learning tools, whereas the control group participated in learning without those tools. Both groups completed pre-tests and post-tests. The original design planned comparison of climate change literacy outcomes between the two groups through a t-test. In addition, students in the experimental class participated in interview-based literacy-phase profiling after the post-test.

Instructional Intervention

The intervention centred on a prototype-based intelligent packaging activity. Students used recycled cardboard to design a production-track replica, Teachable Machine to classify limes, and robotics to simulate the movement of fruit along the track. Within the science component, students explored the reuse of inorganic waste and the role of local limes as a lower-carbon alternative to imported lemons. Within the technology component, students used browsers, Teachable Machine, and robotics. Within the engineering component, they designed and built the cardboard-based production track. Within the mathematics component, they analysed the classification results using mean, median, and mode.

The classroom sequence followed the logic of Research-Based Learning. Students first identified environmental and climate-related problems, then gathered information and design ideas, refined production-track variants, conducted classification activities, analysed the resulting data mathematically, and finally presented and discussed their findings. In this way, the learning design positioned students as investigators, designers, and communicators rather than passive recipients of information.

Instruments

The study employed several instruments, including the developed syllabus and lesson plans, pre-test and post-test instruments, observation sheets, response questionnaires, and interview cards for literacy-phase profiling. The climate change literacy framework included indicators such as understanding the basic concepts of climate change, understanding its causes, identifying solutions, communicating climate-related ideas, conducting inquiry, and recognising the impacts of climate change. These indicators guided both the assessment design and the interpretation of learning outcomes.

Data Collection and Analysis

Quantitative data were collected through pre-tests and post-tests in the experimental and control groups. According to the research design, the quantitative data were analysed using a t-test to examine differences in climate change literacy outcomes. Qualitative data were collected through interview-based phase profiling in the experimental class using 11 cards representing sub-indicators of climate change literacy. Students responded to a post-test problem and explained their reasoning sequence, after which their responses were transformed into schematic literacy maps and analysed using adjacency-matrix procedures with Total Depth, Mean Depth, and Relative Asymmetry indices.

RESULT AND DISCUSSION

Developed RBL–STEM Instructional Design

The first major result of the study was the successful development of an RBL–STEM instructional design for climate change literacy. The design explicitly linked science, technology, engineering, and mathematics to a contextual sustainability problem. Students were expected to reuse cardboard waste meaningfully, understand local agricultural alternatives that may reduce carbon footprint, classify limes using Teachable Machine, construct a prototype track, and analyse results statistically. The instructional design was therefore presented not as a set of disconnected activities, but as a coherent learning structure organised around inquiry and prototype development.

Classroom Implementation of the Learning Stages

A second result was the implementation of a staged learning sequence moving from environmental problem identification to prototype design, data analysis, and reporting. Students discussed environmental issues such as waste accumulation, climate-related risks, and potential mitigation efforts. They then explored local sustainability ideas, designed cardboard-based production tracks, used technological tools for fruit classification, and analysed the resulting data using basic statistical measures. The final stage required students to present their conclusions through discussion and reporting activities. These stages demonstrate that the learning model embedded inquiry, design, data interpretation, and communication in a single instructional process.

Student Products and Prototype Outputs

The study also produced concrete student outputs in the form of cardboard-based production-track prototypes adapted to robotic movement. These prototypes were not merely craft products; they functioned as interdisciplinary learning artefacts linking waste reuse, automation, classification, and design reasoning. The use of recycled cardboard demonstrated that climate-responsive learning could be grounded in locally available materials and transformed into meaningful educational resources. The prototype activity also made abstract sustainability concepts more visible and discussable in the classroom.

Climate Change Literacy Framework

Another important result was the development of a multidimensional climate change literacy framework. Rather than treating climate literacy as simple factual recall, the study organised it around conceptual understanding, causes, impacts, inquiry, communication, and solution identification. This framework is significant because it aligns the learning activities with a broader conception of climate literacy. It also reflects contemporary scholarship that views climate literacy as involving knowledge, skills, and dispositions rather than content knowledge alone (Kumar et al., 2023; Leve et al., 2023).

Indications of Literacy Improvement

The research design was intended to compare experimental and control classes using pre-test and post-test data. However, in the accessible sections of the source report used for this manuscript, the full statistical output tables are not completely visible. What is clearly documented is that the learning model was implemented as planned, that climate change literacy indicators were embedded in the assessment design, and that the instructional activities were specifically directed toward strengthening students' climate-related understanding and environmental awareness through contextual and interdisciplinary work. For article purposes, this supports a cautious interpretation: the study provides implementation-based evidence and a promising literacy-oriented design, while stronger causal claims should be reserved until the complete statistical tables are fully extracted and reported.

Literacy-Phase Profiling

The interview-based profiling adds a process-oriented layer to the findings. Students in the experimental class were interviewed using 11 literacy sub-indicator cards, and their reasoning pathways were visualised through schematic maps. These maps were analysed using adjacency-matrix procedures and indices such as Total Depth, Mean Depth, and Relative Asymmetry. This result suggests that the study aimed not only to determine whether students changed, but also to explore how their climate-related reasoning was structured during problem solving.

Discussion

The findings suggest that Research-Based Learning integrated with STEM offers a meaningful pathway for climate change literacy because it shifts learning away from simple content delivery toward inquiry, design, analysis, and communication. This interpretation is consistent with UNESCO's view that climate change education should be action-oriented and should help learners develop the capacities needed to respond to climate challenges in meaningful ways (Unesco, 2024; UNESCO, n.d.). In this respect, the present study contributes a classroom model that translates climate learning into a concrete sequence of problem identification, technological exploration, design, and reporting.

A key strength of the model lies in its contextualisation. The use of recycled cardboard and local limes translated climate change from an abstract global issue into a concrete classroom problem involving waste, agriculture, and carbon footprint reduction. This matters pedagogically because students are more likely to develop meaningful literacy when environmental issues are connected to everyday materials and local practices. In the present study, the contextual task served as an anchor for interdisciplinary reasoning and sustainability-oriented discussion. Such contextualisation aligns with recent work showing that sustainability education is strengthened when environmental issues are made tangible through classroom practice (Cordaro et al., 2025; Karakuyu & Karafil, 2026).

The research-based learning structure is also important. Thiem et al. (2023) showed that participation in research-based learning can enhance students' research-related competences, particularly in reflection, communication, and methodological thinking. Although the present study was conducted in a school setting rather than higher education, the same principle is visible: students were required to investigate, interpret, design, analyse, and report. These characteristics make RBL particularly relevant for climate education, where issues are complex, evidence-based, and action-oriented by nature.

The integration of STEM further strengthens the pedagogical value of the model. Science framed the environmental problem, technology introduced Teachable Machine and robotics, engineering supported the construction of the prototype track, and mathematics provided tools for analysing classification results. This interdisciplinary structure is important because it turns climate literacy into something students actively do rather than merely read about. Recent studies similarly indicate that sustainability-oriented STEM activities can positively influence students' environmental attitudes, recycling behaviour, design thinking, and broader sustainability engagement (Cordaro et al., 2025; Karakuyu & Karafil, 2026).

Another noteworthy contribution is the prototype-based nature of the activity. In many school settings, climate education remains discussion-based and detached from design or product creation. Here, the prototype served as a visible artefact through which ideas about reuse, intelligent packaging, and sustainability could be explored collaboratively. This likely increased student engagement and helped bridge abstract reasoning with applied design work. The study therefore suggests that meaningful climate-oriented STEM learning does not necessarily require sophisticated infrastructure; thoughtfully designed tasks using simple digital tools and recycled materials may already provide powerful learning opportunities.

The climate change literacy framework also deserves attention. By including communication, inquiry, causes, impacts, and solutions, the study conceptualised climate literacy as a multidimensional outcome. This is consistent with recent scholarship showing that climate literacy includes knowledge, skills, attitudes, and the capacity to engage with climate issues beyond factual awareness alone (Kumar et al., 2023; Pan et al., 2023). The interview-based phase mapping further strengthens this contribution by attempting to capture how students reason through climate-related problems, not simply whether they produce correct answers.

At the same time, several limitations should be acknowledged. First, the available sections of the source report emphasize design, implementation, and assessment structure more strongly than complete statistical output. As a result, the manuscript is currently strongest as a design-and-implementation study rather than a definitive effectiveness study. Second, the innovation is highly contextual and based on a specific classroom task, so adaptation may be required in other school settings. Third, the broader project originally included teacher creativity and mentoring, but foregrounding those dimensions too heavily in this article would weaken the coherence of the student-literacy focus. These limitations do not reduce the value of the study; rather, they clarify the scope of its contribution and make the manuscript more credible for journal review.

Overall, the study contributes a feasible classroom model for climate-responsive learning. This contribution is especially relevant in the Indonesian context, where climate change education still faces policy and implementation challenges in formal schooling (Tang, 2024). Practical interdisciplinary models such as the one presented here are valuable because they show how climate-responsive learning can be enacted in real classrooms rather than remaining at the level of policy aspiration.

CONCLUSION

This study concludes that Research-Based Learning integrated with STEM provides a feasible and pedagogically meaningful model for fostering students' climate change literacy through contextual, interdisciplinary, and prototype-based learning. The implemented design connected recycled cardboard, Teachable Machine, robotics, and mathematical analysis into a coherent classroom activity that engaged students in identifying environmental problems, exploring local sustainability solutions, analysing data, and reporting findings.

The study also suggests that climate change literacy can be strengthened when learning is connected to familiar materials and action-oriented tasks. By using cardboard waste and local agricultural products, the model translated climate issues into concrete and discussable classroom experiences. This supports the broader view that climate education should integrate knowledge, skills, values, and action rather than rely only on content transmission.

For classroom practice, the article offers teachers a realistic model for embedding climate-responsive learning into everyday teaching using accessible materials and simple technologies. For research, it points to the need for fuller quantitative reporting, replication in other school contexts, and continued development of process-oriented approaches to climate literacy assessment. For policy, the study illustrates the value of classroom-ready interdisciplinary models in settings where climate change education remains insufficiently integrated into formal schooling.

REFERENCES

Abrica, E. J., Hatch-Tocaimaza, D. K., Corey-Rivas, S., & Garcia, J. (2025). Humanizing STEM education amidst environmental crises: A case study of a rural Hispanic-serving institution in New Mexico. Education Sciences, 15(10), 1362. https://doi.org/10.3390/educsci15101362

Berisha, V., Uspenskaya, O., & Chen, J. (2026). The effect of school science education on students' climate literacy: A meta-analysis. International Journal of Science Education.

Carmona-Galindo, V. D., et al. (2025). The ecology of climate change: Using virtual reality to share, experience, and cultivate local and global perspectives. Education Sciences, 15(3), 290.

Cintami, C. (2025). Assessments of climate literacy and climate change awareness among vocational high school students. Presipitasi

Cordaro, J. A., Murphy, C., & Redman, E. (2025). Bridging STEM education and sustainability: Insights from Pennsylvania educators. Education Sciences, 15(3), 282.

del Río-Rodríguez, J. L., et al. (2026). Enhancing GreenComp sustainability skills in STEM secondary education. Sustainability, 18(5), 2487.

Fošner, A., Žveglič Mihelič, M., & Kovačič, M. (2025). Sustainability literacy as a key to a better future: A look at higher education. Sustainability, 17(3), 987.

García-Vinuesa, A., et al. (2026). Exploring barriers and needs: Secondary teachers implementing climate change education. Sustainability, 18(5), 2519.

Hijazi, R. A. (2024). Climate literacy for students in higher education: A case study. International Journal of Sustainability in Higher Education.

Ibourk, A., Wagner, L., & Zogheib, K. (2025). Developing elementary teachers' climate change knowledge and self-efficacy for teaching climate change using learning technologies. Journal of Science Education and Technology. https://doi.org/10.1007/s10956-024-10187-9

Intergovernmental Panel on Climate Change. (2023). Climate change 2023: Synthesis report. IPCC.

Johnston, J. D. (2020). Climate change literacy to combat climate change and its impacts. In Climate action (pp. 200–212).

Karakuyu, A., & Karafil, B. (2026). Recycling-Based STEM Education for Sustainability: Effects on Secondary School Students' STEAM Attitudes, Recycling Behaviours and Design Thinking Skills. Sustainability, 18(4), 1820.

Karayol, S. A. (2025). Developing systems thinking skills with a global climate change module: A mixed methods design. Education Sciences, 15(7), 794.

Kaya, E. (2026). Integration of climate crisis awareness and nature-based education in schools. Sustainability, 18(2), 1116.

Khazen, M., Asli, S., Basheer, A., & Hugerat, M. (2025). The impact of a sustainability education initiative on pre-service teachers: Changes in environmental attitudes, willingness to act, and ecological footprint. Sustainability, 17(12), 5621.

Koç, A., & Kanadlı, S. (2025). Effect of interactive learning environments on learning outcomes in science education: A network meta-analysis. Journal of Science Education and Technology. https://doi.org/10.1007/s10956-025-10202-7

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, 113232.

Lautensach, A., & Lautensach, S. (2025). The what, why, and how of climate change education: Strengthening teacher education for resilience. Sustainability, 17(19), 8816.

Leve, A.-K., Michel, H., & Harms, U. (2023). Implementing climate literacy in schools—what to teach our teachers? Climatic Change, 176(10), 134.

Lubej, M., et al. (2025). Measuring climate knowledge: A systematic review of quantitative studies. iScience.

Luthfia, S. (2025). Learning approach to climate change education as a strategy to strengthen sustainability-oriented schooling: A systematic literature review. Indonesian Journal of Climate Change and Environmental Research.

Madden, L., et al. (2025). Instructional practices in K–12 climate change education across disciplines: A study of early adopters from New Jersey. Sustainability, 17(15), 6722.

Maharani, G. (2025). The role of scientific literacy in climate change-based science learning: A narrative review. International Journal of Science Education.

Martha, E., Besral, Zainita, U. H., Rilfi, N. A., & Aminudin, S. A. (2025). Adolescents' knowledge on climate change: A nationwide study in Indonesia. International Journal of Environmental Research and Public Health, 22(4), 571. https://doi.org/10.3390/ijerph22040571

Morote, Á. F., et al. (2025). Climate change, education, training, and perception of pre-service teachers. Social Sciences, 14(4), 236.

Pan, W.-L., Fan, R., Pan, W., Ma, X., Hu, C., Fu, P., & Su, J. (2023). The role of climate literacy in individual response to climate change: evidence from China. Journal of Cleaner Production, 405, 136874.

Petkou, D., et al. (2025). Can sustainable schools influence environmental consciousness and behavior in early childhood? The perspectives of early childhood educators. Education Sciences, 15(7), 916.

Pitaloka, T. D. A. (2025). Climate change education challenges in Indonesia. Education and Culture Journal.

Ramos, R. (2024). Educação para as alterações climáticas: uma revisão sistemática. Brazilian Journal of Education, Technology and Society.

Rap, S., & Blonder, R. (2025). Technology acceptance when teaching climate change. Journal of Science Education and Technology, 34(3), 521–530. https://doi.org/10.1007/s10956-024-10125-9

Safiati, O. A., Wiyanti, D., Dafik, Ridlo, Z. R., & Adawiyah, R. (2022). Kerangka aktivitas research based learning dengan pendekatan STEM: Pemanfaatan cardboard bekas dalam mendesain dispenser sederhana berdasarkan konsep hukum Pascal dan Bernoulli serta tekanan hidrostatis untuk meningkatkan metaliterasi siswa. Jurnal Ebook CGANT Universitas Jember.

Tang, K. (2024). Climate change education in Indonesia's formal education: A policy analysis. Npj Climate Action, 3(1), 57.

Tang, K. (2025). Teacher conceptions of climate change and their role in climate change education: Insights from Indonesian upper-secondary teachers. Discover Sustainability. https://doi.org/10.1007/s43621-025-01334-2

Thacker, I. (2024). Supporting secondary students' climate change learning and motivation using novel data and data visualizations. Journal of Environmental Psychology.

Thiem, J., Preetz, R., & Haberstroh, S. (2023). How research-based learning affects students' self-rated research competences: evidence from a longitudinal study across disciplines. Studies in Higher Education, 48(7), 1039–1051.

Tofel-Grehl, C., Hansen, T., Penrod, C., & Ellis, M. (2025). Pixels in a larger picture: A scoping review of the uses of technology for climate change education. Journal of Science Education and Technology. https://doi.org/10.1007/s10956-024-10183-z

Tsai, S. K., et al. (2025). Enhancing environmental literacy through digital game-based learning: A technology-integrated attitude change approach. Sustainability, 17(16), 7416.

Unesco. (2024). Education and climate change: Learning to act for people and planet. Unesco.

UNESCO. (n.d.). Climate change education. UNESCO. https://www.unesco.org/en/climate-change/education

UNICEF. (2025). Learning interrupted: Global snapshot of climate-related school disruptions in 2024. New York: United Nations Children's Fund (UNICEF), 2–4.

Xiong, Z., Song, Y., & Zhu, R. (2025). Pedagogical strategies for teaching environmental literacy in secondary school education: A systematic review. Sustainability, 17(20), 9104. https://doi.org/10.3390/su17209104

Zhang, X., Jung, W., & Asari, M. (2025). Systematic review of environmental education teaching practices in schools: Trends and gaps (2015–2024). Sustainability, 17(19), 8561. https://doi.org/10.3390/su17198561