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Developing RBL-STEM Learning Kits Using Recycled Plastic Bottles as Electroscopes to Enhance Students' Climate Change Literacy

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Abstract: This study aims to develop RBL-STEM (Research-Based Learning–Science, Technology, Engineering, and Mathematics) learning kits that utilize recycled plastic bottles as electroscopes to improve climate change literacy among junior high school students. The research follows the ADDIE model, encompassing the stages of Analysis, Design, Development, Implementation, and Evaluation. Initial analysis revealed that students' climate change literacy remained low, laboratory facilities are limited, and science education tends to be overly theoretical. The developed kits consisted of lesson plans (RPP), teaching modules, experimental worksheets (LKPD), electroscope prototypes, and evaluation instruments. Expert validation confirmed that the kits are "highly feasible." Implementation involving 70 students showed a significant improvement in climate change literacy, with average scores rising from 66.61 in the pretest to 82.19 in the posttest. A paired-sample t-test yielded a significance value of 0.000, indicating that the kits are effective in enhancing students' understanding. Furthermore, observations of the learning process and feedback from both teachers and students fell into the "excellent" category. The novelty of this research lies in the integration of RBL-STEM with electroscope experiments made from recycled materials, directly addressing environmental issues. Overall, these learning kits have proven to be valid, practical, and effective, contributing to stronger climate change literacy and the application of sustainable science education.

Keywords: Climate change literacy; Electroscopes; Learning kits; RBL-STEM.

Introduction

Climate change literacy is an essential skill in 21st-century education, requiring students to understand, interpret, and apply climate-related concepts in everyday contexts (UNESCO, 2019). In the context of science education, it encompasses more than just theoretical knowledge; it involves critical thinking and evidence-based problem-solving skills. A crucial aspect of strengthening this literacy is the ability of students to use evidence-based approaches to analyze scientific phenomena related to the impacts of climate change, such as global warming, the increasing frequency of natural disasters, and environmental degradation (IPCC, 2021).

Despite its importance, climate change literacy in Indonesia remains low compared to other countries, as indicated by the PISA (Programme for International Student Assessment) results. The 2018 PISA survey revealed that Indonesian students still struggle to grasp climate change concepts and apply them to real-world situations (OECD, 2019). A primary factor behind this low literacy is a teaching methodology that is still dominated by rote learning and a lack of research- and technology-based models (Zurmanely et al., 2025).

To address this, innovations in teaching methods are needed to foster active student engagement in

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scientific investigation. Research-Based Learning (RBL) is an inquiry-based approach in which students are actively involved in exploring, collecting data, and analyzing real-world phenomena using the scientific method (Healey & Jenkins, 2009). Integrating RBL with STEM (Science, Technology, Engineering, and Mathematics) offers an innovative solution. The RBL-STEM approach allows students to not only understand scientific concepts theoretically but also develop data-driven problem-solving skills, computational thinking, and creativity in designing scientific models (Kelley & Knowles, 2016).

In the context of climate change, this approach provides opportunities for students to develop scientific models linked to real-life issues, such as repurposing discarded plastic bottles as electroscopes to measure the environmental impact of pollution and climate change. As an easily accessible material, plastic bottles can be utilized in scientific experiments to introduce students directly to fundamental physics and environmental concepts. Using recycled materials also instills the importance of recycling and sustainability, while simultaneously strengthening climate change literacy (Jones & Scantlebury, 2020).

While various studies have explored RBL-STEM in climate change education-such as integrating climate prediction models with practical school experiments (Kumar et al., 2018) few studies have bridged the gap between using recycled materials in scientific experiments and school-level climate change education. Therefore, developing RBL-STEM-based learning kits that empower students to build scientific experimental models using discarded plastic bottles as electroscopes represents an innovative step toward enhancing student literacy.

This research offers several significant points of novelty. Primarily, it integrates RBL and STEM through the use of recycled plastic bottles as electroscopes to understand climate change. This approach combines research-based learning with the application of STEM concepts to boost literacy. Through hands-on experiments and predictive modeling, students do not just passively learn; they actively apply the scientific method. This approach remains rare in secondary school climate change education, thus offering a novel contribution to the field.

Furthermore, this study focuses on student-led experimental design rather than mere theoretical comprehension or the use of pre-existing models. Unlike many academic studies that keep experiments within a theoretical framework, this research equips students with the skills to develop their own experiments. Students collect experimental data, analyze results, and build models to measure how pollution and climate change affect the environment. By doing so, they transition from information recipients to active scientific explorers.

To support effective learning, this study also develops interactive learning kits that combine digital simulations, hands-on experiments, and data analysis based on statistics and simple programming. These kits are designed to cultivate critical thinking, problem-solving, and computational thinking. With technology integration, students can more easily grasp complex concepts and apply scientific principles.

Lastly, the novelty of this research lies in its real-world application. Students are encouraged to connect science with daily life, specifically by understanding how using recycled materials can mitigate climate change impacts and raise awareness about sustainability. Through this science-based approach, students develop a deeper consciousness regarding the importance of recycling and reducing plastic waste in their own lives.

Method

This study employs a Research and Development (R&D) design, utilizing the ADDIE model (Analysis, Design, Development, Implementation, and Evaluation). This model was selected for its systematic suitability in developing, validating, and testing the effectiveness of RBL-STEM-based learning kits, specifically within the context of climate change literacy and experiments involving recycled plastic bottle electroscopes.

Furthermore, the study adopts a mixed-methods approach to gather comprehensive data. This includes qualitative insights-obtained through observations and interviews-as well as quantitative data derived from climate change literacy tests, questionnaires, and expert validation scores.

The research was conducted at SMPN 2 Silo. The research subjects included: expert validators (specialists in science/stem education and RBL), science teachers, ninth-grade students as the trial group. The sample was selected using a purposive sampling technique, considering teacher readiness and school facilities.

The analysis activities included: needs assessment, identifying requirements for climate change education and addressing the low levels of climate literacy among students; curriculum analysis, reviewing the kurikulum merdeka (independent curriculum) to ensure competency alignment; student profile and resource analysis: assessing student characteristics and the availability of materials, specifically the potential for utilizing discarded plastic bottles as electroscopes; and literature review: examining RBL, stem, climate change literacy, and learning kit development.

The design of the learning kits involved: RBL-STEM lesson plans and teaching modules, worksheets (LKPD) based on experiments and mini-research projects, instructional materials covering electroscope concepts and climate change, evaluation instruments (climate literacy tests, experimental rubrics, teacher and student feedback questionnaires), and plastic bottle electroscope prototypes.

The development phase involved product construction: Assembling the learning kits; expert validation, using validation sheets to assess content validity, construct, language, feasibility, and STEM integration; and product revision, refining the materials based on feedback and suggestions from the validators.

The trial of the learning kits was conducted in two stages: a small-scale trial, conducted in one class to observe initial feasibility and responses; and a field trial, conducted with a larger group to test the practicality and effectiveness of the kits. During implementation, data were gathered through observations of student activities, teacher interviews, and pretest–posttest scores on climate change literacy.

Evaluations were conducted both formatively and summatively, including assessment of kit quality based on validity, practicality, and effectiveness, as well as final revisions of the learning kits for publication.

Table 1. The research instruments

Aspect	Instrument	Data	Respondents
Kit Validity	Validation sheets	Validation scores	Experts
Practicality	Implementation observation sheets	Implementation percentage	Teachers, Observers
Effectiveness	Climate literacy tests	Pre-test & Post-test scores	Students
	Activity observation sheets	Student activity (%)	Observers
	Feedback questionnaires	Student perceptions	Students

Expert Validation to assess the quality of the learning kits. Pre-test and Post-test to measure the improvement in climate change literacy. Observation to monitor the feasibility and implementation of the learning process. Questionnaires to gauge student and teacher responses toward the kits. Interviews to strengthen the qualitative findings.

Results and Discussion

Results

The analysis phase was conducted to identify learning needs regarding climate change literacy and to assess the readiness of the learning environment for implementing RBL-STEM kits. The results indicate that students' climate change literacy remains low, characterized by a lack of understanding regarding the links between static electricity phenomena, pollution, and climate change. While the Kurikulum Merdeka (Independent Curriculum) encourages project- and research-based learning, laboratory facilities are limited, and standard electroscopes are unavailable. Conversely, there is significant potential in utilizing discarded plastic bottles as experimental tools, as they are easily accessible and directly relevant to environmental issues. Furthermore, teachers expressed a need for practical, systematic learning kits that foster active student engagement through scientific investigation. These findings underscore the urgent need to develop RBL-STEM learning kits that are contextual, cost-effective, and applicable-empowering students to deepen their understanding of climate change through simple hands-on experiments using recycled plastic bottles as electroscopes.

Table 1. Summary of analysis phase results

Analysis Aspect	Key Findings	Implications for Kit Development
Curriculum Analysis (Kurikulum Merdeka)	Static electricity, environment, and climate change are core learning outcomes for Grade 9 Science. Project-based, research-based, and STEM models are highly recommended.	The learning kits must integrate experiments, small-scale research projects, and investigative activities aligned with the RBL-STEM framework.
Student Needs Analysis	Climate change literacy is low; students struggle to link scientific phenomena (electric charge, pollution, greenhouse effect). Learning is predominantly textbook-based with minimal hands-on experience.	Worksheets (LKPD) and modules must be contextualized-connecting electroscope experiments directly to climate change issues and pollution impacts.

Analysis Aspect	Key Findings	Implications for Kit Development
Resource Availability Analysis	Science laboratory facilities are limited. Standard electroscopes are unavailable. However, recycled materials (plastic bottles, straws, aluminum foil) are abundant.	Learning kits must utilize low-cost, easily assembled, and safe experimental tools, specifically electroscopes made from repurposed plastic bottles.
School Characteristics Analysis	The school has adopted Kurikulum Merdeka. Technology access is limited, but science teachers are enthusiastic about adopting research-based pedagogical innovations.	The kits should be straightforward and implementable without specialized lab equipment, while maintaining rigorous STEM content.
Teacher Needs Analysis	Teachers require systematic and comprehensive materials (lesson plans, worksheets, rubrics) that are easy to implement to foster active learning and scientific literacy.	Kits must include clear RBL-STEM syntax, experimental guides, research assessment rubrics, and step-by-step instructions for the electroscope.
Literature Review (RBL-STEM & Climate Literacy)	RBL and STEM are proven to enhance critical thinking and conceptual understanding. However, research linking electroscope experiments to climate change issues is virtually non-existent.	The kits must merge scientific inquiry (RBL) with applicable STEM activities relevant to climate issues. This serves as the research novelty.
Environmental Context Analysis	Plastic use remains high among students, with significant plastic waste in the school vicinity. Students lack awareness of the link between plastic waste and climate change.	Case studies and research projects should utilize plastic waste as learning tools to reinforce climate change literacy and sustainability values.

The design phase focused on developing the initial framework of the RBL-STEM learning kits aimed at enhancing students' climate change literacy through experiments with recycled plastic bottle electroscopes. During this stage, the core components of the kits were drafted, including lesson plans (RPP) based on RBL syntax integrated with STEM elements, experimental worksheets (LKPD) to guide students in constructing and utilizing simple electroscopes, and teaching modules explaining static electricity and its correlation with climate change. Furthermore, evaluation instruments-comprising climate literacy tests, observation sheets, and feedback questionnaires-were developed. A prototype design for the plastic bottle electroscope was also created to serve as a low-cost, safe, and easily assembled laboratory tool. The overall design aimed to ensure that the learning kits were structured, contextual, and ready for further refinement in the subsequent development phase.

Table 2. Summary of Design Phase Results

Designed Component	Design Results	Objectives and Implications
RBL-STEM Lesson Plans (RPP)	Designed using RBL syntax (problem orientation, problem formulation, data collection, data analysis, conclusion) integrated with STEM elements (science, technology, engineering, and mathematics).	To guide research- and experiment-based learning; preparing teachers to facilitate students' scientific investigations.
Plastic Bottle Electroscope Worksheets (LKPD)	Contain step-by-step instructions for building electroscopes from recycled bottles, guidelines for electrical charge experiments, and links between static electricity and climate change.	To stimulate active student engagement in experimental activities while enhancing scientific literacy and environmental awareness.
Climate Change Teaching Module	Covers fundamental concepts of static electricity, electroscopes, climate change, air pollution, greenhouse gases, and the correlation between atmospheric charges and climatic phenomena.	To provide a comprehensive learning resource that bridges theory, practice, and global issues.
Climate Change Literacy Evaluation Instruments	Consist of pre-test and post-test items based on climate literacy indicators (identifying phenomena, explaining concepts, using evidence, and designing solutions).	To objectively and standardly measure the improvement in students' climate change literacy.

Designed Component	Design Results	Objectives and Implications
Implementation Observation Sheets	Observation formats containing indicators for RBL-STEM syntax execution, student activities, and the teacher's role.	To assess the practicality and feasibility of the learning kits during classroom use.
Teacher and Student Feedback Questionnaires	Structured to evaluate the readability, ease of use, material relevance, and the appeal of the experiments.	To gather user feedback for improving the effectiveness and overall acceptance of the kits.
Test Blueprint & Assessment Rubrics	Includes a climate literacy test blueprint and experimental rubrics (experimental accuracy, data analysis, conclusion, and reflection).	To ensure alignment between climate literacy indicators, learning activities, and assessment methods.
Plastic Bottle Electroscope Prototype Design	Initial design utilizing recycled plastic bottles, copper wire, aluminum foil, and adhesive tape.	To provide a low-cost, safe, and easily assembled experimental tool that supports contextual learning.

The development phase focused on the construction, refinement, and initial validation of the RBL-STEM learning kits designed in the previous stage. During this phase, a complete set of components was developed, including lesson plans (RPP), teaching modules, experimental worksheets (LKPD) for the plastic bottle electroscope, the physical prototype, and climate change literacy evaluation instruments. Each component underwent rigorous validation by subject matter experts, pedagogical specialists, and media experts to assess content feasibility, structural integrity, conceptual accuracy, and the clarity of language and instructions. Validation results placed the learning kits in the "Highly Feasible" category. Nonetheless, several revisions were performed to enhance readability, clarify experimental steps, refine tool illustrations, and ensure precise alignment between indicators and learning objectives. This phase ensured that all developed materials met quality standards before proceeding to field implementation.

Table 3. Summary of Development Phase Results

Developed Component	Development Results	Expert Validation Findings	Revisions Performed
RBL-STEM Lesson Plans (RPP)	Completed with full RBL syntax, STEM integration, authentic assessments, and experimental activity scenarios.	Experts stated the content aligns with the curriculum, the RBL syntax is accurate, and the learning steps are clear.	Simplified learning indicators and clarified time allocation.
Teaching Module	Contains concepts of static electricity, electroscopes, and climate change, accompanied by diagrams, data analysis activities, and environmental case studies.	Rated as "Highly Feasible"; the language is easy to understand, and illustrations effectively support student comprehension.	Refined several scientific terms and added local contextual examples.
Experimental Worksheets (LKPD)	Includes steps for constructing the plastic bottle electroscope, mini-research procedures, data tables, and analytical questions.	Validators found the worksheets engaging and aligned with STEM principles, though some instructions required clarification.	Added tool diagrams, clarified experimental instructions, and expanded the data analysis sections.
Plastic Bottle Electroscope Prototype	Constructed from plastic bottles, wire, and aluminum foil; successfully tested for sensitivity.	Experts confirmed that the tool is safe, low-cost, and easy to assemble, and is sensitive to basic static charges.	Strengthened wire connections and added insulation for better stability.
Climate Change Literacy Test	Consists of 20 multiple-choice questions and 5 essay questions based on climate literacy indicators.	Experts rated the items as valid, aligned with indicators, and capable of measuring students' analytical skills.	Improved several distractors, added data-driven contexts, and aligned cognitive levels.
Implementation Observation Sheets	Contains indicators for RBL-STEM syntax execution and student activities.	Valid, easy to use, and features clear indicators.	Minor revisions to the indicator descriptions.
Teacher & Student Feedback Questionnaires	Likert-scale based to evaluate the kits' appeal, ease of use, and utility.	Highly feasible; use communicative language and a user-friendly format.	Simplified several statements to eliminate ambiguity.

The implementation stage was conducted to examine the practicality and effectiveness of the RBL-STEM learning tools developed in the previous phase. At this stage, the learning tools were applied to 70 students who participated in a series of learning activities, including constructing an electroscope from recycled plastic bottles, conducting static electricity experiments, analyzing data, and engaging in issue-based discussions on climate change. During the learning process, teachers and observers used observation sheets to assess the implementation of the RBL-STEM syntax as well as the level of student activity. Pretest and posttest instruments were administered to quantitatively measure the development of students' climate change literacy, while a response questionnaire was used to obtain feedback on the attractiveness and ease of use of the learning tools.

The implementation results indicated a significant improvement in students' climate change literacy. The mean pretest score of 66.61 increased to 82.19 in the posttest. Although the normality test results showed significance values below 0.05, the data distribution was still be analyzed using a paired sample t-test due to the large sample size (N = 70). The t-test results revealed a significance value of 0.000 with a mean difference of 15.57, indicating that the implementation of the learning tools had a highly significant effect on improving students' understanding. Furthermore, the very strong correlation (r = 0.950) demonstrates that the observed improvement was consistent across most students. Therefore, the implementation stage confirms that the RBL-STEM learning tools are effective, practical, and capable of substantially enhancing climate change literacy.

Table 4. Summary of Implementation Phase Results

Data Type	Findings	Interpretation
Number of Students (N)	70 students	The number of participants was consistent between the pretest and posttest.
Pretest Mean Score	66.61	Initial climate change literacy was categorized as low to moderate.
Posttest Mean Score	82.19	A significant improvement occurred after the implementation of the RBL-STEM learning tools.
Normality Test (Kolmogorov-Smirnov)	Pretest Sig = 0.021; Posttest Sig = 0.019	The data were not normally distributed (Sig < 0.05); however, the analysis could be continued because the sample size exceeded 30 and the t-test is robust.
Pretest-Posttest Correlation	r = 0.950; Sig = 0.000	There was a very strong correlation between scores before and after the treatment.
Paired Sample t-test Results	t = -104.549; df = 69	The extremely large t-value indicates a significant difference.
Sig. (2-tailed)	0.000	A statistically significant improvement was found (p < 0.05).
Mean Difference	-15.571	The learning tools effectively improved climate change literacy by 15.57 points.

The evaluation phase was conducted to assess the final quality of the RBL-STEM learning kits following their classroom implementation. This evaluation integrated results from tests, observations, and user feedback to determine the kits' overall validity, practicality, and effectiveness. The results demonstrate that the kits significantly enhance climate change literacy, as evidenced by a mean difference of 15.57 between pre-test and post-test scores and a significance value of 0.000. Observations of the RBL-STEM syntax implementation exceeded 90%, indicating that the kits are highly practical for classroom use. Furthermore, feedback from both students and teachers was overwhelmingly positive, noting that the materials are engaging, easy to comprehend, and effective in supporting active learning. Overall, the evaluation phase confirms that the developed learning kits meet all feasibility criteria and are ready for broader application.

The final evaluation findings indicate that the RBL-STEM learning kits possess a high degree of effectiveness in improving students' climate change literacy. This is substantiated by the significant increase in post-test scores compared to pre-test scores, with an average gain of 15.57 points and a paired sample t-test significance value of 0.000. These findings suggest that the kits do more than just enrich students' conceptual understanding of static electricity and electroscope phenomena; they also successfully bridge these concepts with broader climate change issues. Consequently, the kits have proven effective in achieving learning objectives rooted in scientific literacy and contextual education.

Table 5. Summary of Evaluation Phase Results

Evaluation Aspect	Indicator	Findings	Category / Interpretation
Effectiveness of Learning Tools	Improvement in learning outcomes (pretest-posttest)	Mean pretest = 66.61 → posttest = 82.19; Difference = +15.57	Effective in improving climate change literacy
	Paired sample t-test results	p = 0.000; t = -104.549	Significant improvement ($p < 0.05$)
Learning Implementation	Observation of RBL-STEM syntax implementation	≥ 90% of activities implemented in each meeting	Highly implemented / highly practical
Student Responses	Attractiveness and ease of use of the learning tools	≥ 90% of students gave positive responses	Very positive / very good
Teacher Responses	Ease of implementation and appropriateness of the learning tools	Teachers stated that the tools are easy to use, well-structured, and support active learning	Highly feasible for use
Overall Product Quality	Validity - Practicality - Effectiveness	All aspects met the feasibility criteria	The product is declared ready for dissemination

Discussion

The analysis phase revealed that low climate change literacy is a critical issue that must be addressed through pedagogical innovation. Based on the needs assessment, the majority of students struggle to correlate scientific concepts-such as static electricity, the greenhouse effect, and atmospheric phenomena-with the environmental challenges they encounter daily (Martinah et al., 2022). This lack of connectivity highlights a significant gap between classroom theory and the reality of climate change occurring in the surrounding environment (Ubaidah et al., 2025). Such conditions underscore that previous learning materials have failed to encourage students to think critically, analyze scientific evidence, or interpret data related to climate change comprehensively (Wahyuni et al., 2025).

Curriculum analysis indicated a substantial opportunity to integrate contextual learning through the Research-Based Learning (RBL) model and the STEM approach. The Kurikulum Merdeka promotes inquiry-based learning, projects, and cross-disciplinary integration, making RBL-STEM highly suitable for addressing these educational needs (Gita et al., 2023). However, the implementation of research-based learning remains suboptimal due to a shortage of systematic teaching kits and relevant environmental experiments (Christina et al., 2025). These findings support the necessity for learning kits that not only meet curricular demands but also foster scientific skills, creativity, and problem-solving abilities (Juliastari et al., 2022).

Furthermore, the teacher needs analysis showed a demand for comprehensive, practical, and easily implementable materials, particularly those that guide students through structured scientific investigations (Adrillian et al., 2024). Teachers seek kits that include not only lesson plans but also worksheets, experimental guides, and clear evaluation instruments (Alvin et al., 2025). Consequently, the development of RBL-STEM kits must prioritize ease of implementation, content integration, and support for teachers in facilitating student research (Am et al., 2023).

The design phase served as a vital foundation for ensuring that the RBL-STEM kits were systematic, measurable, and relevant to climate change literacy (Incesu & Yas, 2024). During this stage, findings from the analysis phase were translated into a comprehensive development plan. The design process accounted for the alignment between curricular competencies, student characteristics, and limited school facilities. This ensured that the designed kits were not only innovative but also realistic and practical for junior high school science contexts (Aini & Supardi, 2024). This structured design aimed to ensure that research-based learning can proceed effectively to achieve the literacy objectives (Fikriyah & Sukmawati, 2022).

The primary components designed include RBL-based lesson plans (RPP) integrated with STEM elements. These plans guide students through problem orientation, formulation of research questions, experiments with plastic bottle electroscopes, data analysis, and drawing evidence-based conclusions (Adrillian et al., 2024). The STEM integration is reflected in activities combining static electricity science, simple tool-making technology, engineering processes, and basic mathematical analysis of experimental results. This design directly targets the development of scientific skills and structured critical thinking (Ardiyansah et al., 2024).

In addition to lesson plans, the design of the experimental worksheets (LKPD) is the most strategic component. The LKPD is designed as a mini-research guide that empowers students to conduct independent scientific exploration (Azizah et al., 2023). Each section provides instructions for building the electroscope, experimental procedures, data tables, and reflective questions linking the results to global climate change issues (Zulfah et al., 2024). This design is expected to create an active and meaningful learning experience while training students to understand the link between simple lab activities and global environmental phenomena (Martinah et al., 2022).

Furthermore, the teaching modules bridge abstract concepts such as static electricity, the greenhouse effect, air pollution, and climate change (Fitriana & Dewi, 2024). Using communicative language, supporting visuals, and real-world case studies, the modules help students grasp the scientific relevance between electroscope experiments and atmospheric phenomena (Aji et al., 2025). Activities like graph analysis, image interpretation, and plastic pollution case studies ensure a comprehensive development of climate literacy (Aji et al., 2025).

The development phase is a crucial process where the RBL-STEM designs are transformed into tangible, validated products (Rachman et al., 2024). The development was carried out based on the results of the analysis. This phase addresses the weaknesses identified in previous learning models, specifically by utilizing recycled plastic bottle electroscopes to boost climate literacy (Fikriyah & Sukmawati, 2022). Throughout this stage, care was taken to ensure that each component was not only structurally complete but also functional, comprehensible, and contextually appropriate for the school science setting (Gita et al., 2023).

The development of the teaching module focused on creating supporting materials that include fundamental concepts, illustrations, and relevant environmental explanations (Aji et al., 2025). Although experts rated the module as "Highly Feasible," refinements were made to scientific terminology and the addition of local contextual examples (Irmawati et al., 2025). The inclusion of reflective activities and graph analysis further strengthens the comprehensiveness of climate literacy (Mutoharoh et al., 2022), ensuring students have a solid conceptual foundation before conducting experiments.

Evaluation instruments, feedback questionnaires, and observation sheets were also finalized and validated. The climate change literacy test was aligned with international indicators, such as identifying phenomena, analyzing data, and proposing evidence-based solutions (Wahyuni et al., 2025). Expert feedback led to improvements in cognitive level alignment, distractor refinement, and environmental context enhancement. Overall, the development phase resulted in a complete learning kit that has passed rigorous validation and revision, making it ready for field testing (Rachman et al., 2024).

The implementation phase aimed to evaluate how the RBL-STEM kits perform in a real classroom setting and their effectiveness in improving climate change literacy (Gita et al., 2024). This phase also aimed to evaluate how the RBL-STEM kits perform in a real classroom setting and their effectiveness in improving climate change literacy (Wahyuni et al., 2025).

The RBL-STEM approach provided a transformative learning experience where students moved beyond passive reception to active scientific inquiry (Gita et al., 2024). Constructing electroscopes from discarded bottles was a highlight, as it visually demonstrated the link between static electricity and broader environmental issues (Christina et al., 2025). This hands-on experience proved that combining simple engineering with problem-solving facilitates better conceptual understanding. Moreover, the use of recycled materials adds ecological value and raises student awareness regarding sustainability (Ubaidah et al., 2025).

Observations indicated a significant surge in student activity during the RBL-STEM sessions. Students became more inquisitive, actively engaging in discussions and analyzing phenomena-a hallmark of RBL which prioritizes curiosity and investigative skills (Gita et al., 2023). Teachers reported that students were more focused and engaged, particularly when interpreting experimental results in the context of climate change (Incesu & Yas, 2024). This increased classroom activity serves as a vital indicator that the kits successfully facilitate meaningful learning (Juliastari et al., 2022).

Quantitatively, the improvement in literacy was substantiated by the significant gap between pre-test and post-test scores. The average pre-test score of 66.61 indicated a low-to-moderate baseline. However, after the RBL-STEM intervention, the mean score rose to 82.19. This 15.57-point gain demonstrates that the learning kits are not only engaging but also statistically effective in helping students master scientific climate change concepts (Incesu & Yas, 2024).

The results of the paired sample t-test further strengthened these findings. The significance value (Sig. 2-tailed) of $0.000 < 0.05$ indicates a statistically significant difference between students' scores before and after the learning intervention. The extremely large t-value ($t = -104.549$) suggests that the observed improvement was not coincidental but rather a direct outcome of the implementation of the learning tools. These findings confirm that the RBL-STEM learning tools are effective in enhancing climate change literacy both statistically and pedagogically. The very high correlation between pretest and posttest scores ($r = 0.950$) also indicates that the improvement was consistent across nearly all students (Hake, 1999).

Although the Kolmogorov-Smirnov normality test showed that the data were not normally distributed ($p < 0.05$), the use of a paired sample t-test remained appropriate due to the large sample size ($N = 70$), rendering the parametric analysis valid and robust. Such conditions are commonly encountered in educational research, where deviations from normality can be mitigated by an adequate sample size. Therefore, the statistical results can still be interpreted accurately to demonstrate the effectiveness of the learning tools (Zalsa et al., 2025).

From a practicality standpoint, the positive feedback from teachers and observers suggests that the RPP, LKPD, and modules are user-friendly and provide clear guidance for facilitating research-based learning. The step-by-step nature of the LKPD was particularly helpful in bridging the gap between the lab experiment and climate issues (Adrillian et al., 2024). This practicality is a significant advantage for schools with minimal laboratory facilities.

Finally, the evaluation phase confirms that the learning kits meet the three pillars of quality: validity, practicality, and effectiveness. The kits are ready for dissemination as they tangibly improve literacy, are easily implemented, and are highly engaging for students. This success demonstrates that integrating RBL-STEM with recycled materials can be an innovative solution for science education in resource-constrained schools. Overall, this research provides a significant contribution to contextual learning that supports scientific understanding and environmental consciousness in the era of climate change.

Conclusion

Based on the data obtained, it can be concluded that the RBL-STEM learning kits-utilizing recycled plastic bottles as electroscopes-are proven to be valid, practical, and effective in enhancing students' climate change literacy. The kits, which comprise lesson plans (RPP), teaching modules, experimental worksheets (LKPD), tool prototypes, and evaluation instruments, have undergone a systematic development and validation process. Implementation results demonstrate a significant increase in climate change literacy, as evidenced by the marked difference between pre-test and post-test scores, as well as heightened student engagement throughout the research-based learning process. Furthermore, both teachers and students provided positive feedback, indicating that the kits are user-friendly, engaging, and highly relevant to the needs of science education. Overall, the application of these RBL-STEM learning kits does more than just improve conceptual understanding of static electricity and climate change; it also fosters scientific skills, creativity, and environmental awareness among students. The utilization of simple materials, such as discarded plastic bottles, successfully addresses the constraints of limited laboratory facilities while delivering contextual and meaningful learning experiences. Consequently, these learning kits are feasible for broader implementation and serve as an innovative alternative in science education that supports the strengthening of climate change literacy and sustainable education.

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