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Improving Environmental Literacy Through Ecobrick-Based Project-Based Learning in Second-Grade Elementary Students

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Abstract: Limited research has examined how ecobrick projects can be organized within project-based learning to develop environmental literacy in the early primary grades. This study aimed to examine whether and how ecobrick-based Project Based Learning (PjBL) improved the environmental literacy of second-grade students at a public elementary school in Malang City, Indonesia. Classroom Action Research was conducted in two cycles with 23 students in the 2025/2026 academic year, and each cycle comprised planning, action, observation, reflection, and evaluation. Data were collected through a pretest, a Cycle I posttest, and a Cycle II posttest covering cognitive, affective, and behavioral indicators, together with teacher observations. Mean scores increased from 36.22 in the pretest to 64.78 in Cycle I and 84.74 in Cycle II, and learning mastery rose from 30.43% to 73.91% and then to 91.30%. In Cycle II, 69.57% of students were in the high normalized gain category, 30.43% were in the moderate category, and none were in the low category. The results indicate that ecobrick-based PjBL with small groups and direct observation was associated with improved environmental literacy in this class, and further studies with comparison groups and delayed posttests are needed.

Keywords: environmental literacy; ecobrick; project-based learning; classroom action research; elementary school; normalized gain.

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INTRODUCTION

Plastic waste has become a visible environmental concern, and schools are expected to prepare children to respond to it. According to Geyer et al. (2017), about 6,300 million metric tons of plastic waste had been generated by 2015, and roughly 79% of it had accumulated in landfills or the natural environment. Research by Lebreton et al. (2017) estimated that between 1.15 and 2.41 million metric tons of plastic waste enter the ocean from rivers each year, with the 20 most polluting rivers, mostly located in Asia, accounting for 67% of the global total, and Meijer et al. (2021) later reported that more than 1,000 rivers account for 80% of annual riverine emissions, with small urban rivers among the most polluting. Recent evidence indicates that projected growth in plastic waste exceeds current mitigation efforts, which underscores the need to build environmental competence early in schooling (Borrelle et al., 2020).

Environmental literacy has been used as an organizing concept in environmental education to describe what learners need to understand and do in relation to environmental problems. Szczytko et al. (2019) described environmental literacy through four components, namely ecological knowledge, environmental hope, cognitive skills, and behavior, and validated a short instrument that measures these components among adolescents. Research by Braun et al. (2018) examined changes in environmental knowledge, attitudes, and behavior in outdoor education programs and found that country of residence and urban or rural residence best explained program effects, which indicates that environmental literacy outcomes are studied in relation to both individual and contextual conditions. Consistent with these perspectives, the present study treats environmental literacy through cognitive, affective, and behavioral indicators.

A recurring concern in environmental education is that environmental knowledge does not automatically translate into environmentally responsible action. In a longitudinal study of children followed from age 7 to 18, Otto et al. (2019) found that the relation between environmental attitude and behavior was modest at age 10, substantial at age 14, and absent at ages 7 and 18. Evans et al. (2018) followed children from age 6 to 18 and reported that attitudes and behaviors at age 6 did not predict behavior at age 18. According to Braun et al. (2018), contextual factors were more likely to drive environmental behaviors than environmental knowledge or attitudes, which points to the value of learning experiences in which learners investigate and act on environmental issues.

Empirical studies in environmental education have examined which learning experiences and learner characteristics are associated with children's environmental outcomes. Szczytko et al. (2019) reported weak relationships between cognitive skills and behavior in their validation data, which indicates that the link between knowing and acting merits further examination. Otto et al. (2019) suggested that education for sustainable development should address environmental attitude and behavior at the same time, which highlights that learning designs should consider how knowledge is translated into action. These observations indicate that learning activities for young children may benefit from combining concepts with concrete tasks and direct experience.

Direct experience in natural and authentic settings has been proposed as one pathway for developing children's environmental responsiveness. Soga et al. (2016) surveyed 397 elementary schoolchildren in Tokyo and reported that the frequency of direct and vicarious experiences of nature was positively associated with children's affective attitudes and willingness to conserve biodiversity. Research by Otto and Pensini (2017) found that connectedness to nature and environmental knowledge were both related to children's ecological behavior, with connectedness to nature explaining 69% of the variance and knowledge explaining 2%. These findings point to the value of direct experience, and the conditions under which such experience supports environmental learning in primary classrooms require further clarification.

Preliminary observations and a brief interview with the second-grade teacher at a public elementary school in Malang City, Indonesia, indicated that students frequently littered within the school environment, including the classroom, and showed limited concern for cleanliness. The teacher also reported that students had limited understanding of the importance and benefits of maintaining the environment and that the learning media available for environmental topics were not sufficiently engaging. Kuo et al. (2018) examined 318 public elementary schools in Chicago and reported that schoolyard tree cover was associated with both reading and math performance, which suggests that the condition of the school environment is relevant to academic outcomes. These local conditions, together with the evidence on discrepancies between knowledge and action, point to the need for a learning approach that connects environmental concepts with students' daily experiences in the classroom.

Project-based learning (PjBL) has been examined extensively as an approach that organizes learning around meaningful products and problems. Djordjevic et al. (2026) compared project-based learning in geography with traditional teaching among students in their final year of primary school, with an experimental group receiving project-based learning and a control group continuing with traditional approaches. The results favored project-based learning in the formation of environmental values, attitudes, and pro-environmental behavior, although the authors noted that the findings cannot be generalized to the entire population (Djordjevic et al., 2026). These findings indicate that project-based designs are a plausible option for environmental education in the primary grades, and they motivate closer attention to how such designs are organized for younger pupils.

Ecobricks, which are PET bottles packed with plastic waste, offer a concrete project through which students can handle the material they are learning about. Oyinlola et al. (2018) reported a bottle house project in which bottle-based construction was used to develop affordable homes in a low-income community in Nigeria, which illustrates that the technique has been applied in community settings. Many available studies on ecobricks have addressed their material performance, as in the density and strength tests reported by Sze et al. (2026), and research remains limited regarding how ecobrick projects can be organized within PjBL cycles to develop environmental literacy in the early primary grades. Classroom implementation of PjBL also involves decisions about

teacher facilitation and group work arrangements, which makes cyclical refinement of classroom practice a relevant strategy.

Classroom Action Research (CAR) provides a cyclical structure of planning, action, observation, and reflection through which teachers refine practice in their own classrooms. In this design, participants examine and change their own practices across successive cycles, so that each cycle informs the next. Wang et al. (2023) compared dyad and quad groups in two experiments with 62 undergraduate students and found that learning outcomes were not significantly affected by group size, whereas dyads showed more communication and interaction during learning, which supports examining group arrangement as one element of refinement between cycles. This aspect has received limited attention for second-grade students, where the combined influence of ecobrick projects, group arrangement, and direct observation of the surrounding environment on environmental literacy is still not well documented.

This study aims to examine whether and how an ecobrick-based PjBL approach, implemented through two CAR cycles, improves the environmental literacy of second-grade students at a public elementary school in Malang City, Indonesia. This study examines ecobrick projects within PjBL in early primary environmental education, and it documents cycle-level refinements in group size and learning stimulus within this context. The study is guided by the following research questions: 1) To what extent do students' environmental literacy scores and learning mastery change from the pretest to Cycle I and Cycle II? 2) How are students distributed across normalized gain categories in Cycle I and Cycle II? 3) How do the changes in group arrangement and problem stimulus between the cycles relate to students' participation and literacy development as observed by the teacher? The findings are expected to inform teachers and school leaders who plan project-based environmental learning in the early grades.

METHODS

Research Design

This study employed Classroom Action Research following the cyclical model associated with Kemmis and McTaggart, in which the teacher and researcher plan an action, implement it, observe its effects, and reflect on the results. Following the view of action research presented by Kemmis (2009), the participants examined their own classroom practice and revised it between cycles. Two cycles were conducted, and each cycle consisted of planning, action implementation, observation, reflection, and evaluation. The researcher and the classroom teacher worked collaboratively at every stage, and the reflections from Cycle I informed the planning of Cycle II.

Figure 1 presents the research flow from the pretest through the two Classroom Action Research cycles to the Cycle II posttest. The sequence shows the planning, action, observation, reflection, and evaluation stages in each cycle, with the Cycle I reflection informing the revisions implemented in Cycle II.

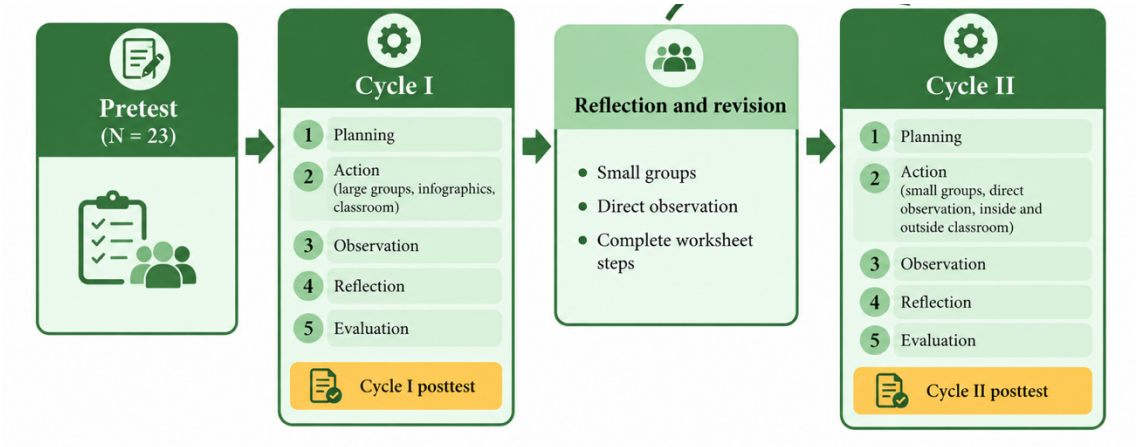


Figure 1. Research flow of the two-cycle Classroom Action Research

Figure 1 shows the five components used in both cycles and identifies the reflection stage after Cycle I as the point at which group arrangement and problem stimulus were revised. The pretest preceded Cycle I, while the Cycle I and Cycle II posttests followed their respective learning actions.

Participants and Setting

The study was conducted at a public elementary school in Malang City, East Java, Indonesia, during the 2025/2026 academic year. The participants were 23 second-grade students who were taught by their regular classroom teacher in collaboration with the researcher. Preliminary observations and a brief interview with the teacher indicated limited understanding of environmental care, frequent littering, and a lack of engaging media for the "Love the Environment" material. All 23 students took part in the activities and in every test occasion, and the class was treated as one unit of analysis.

Intervention: Ecobrick Project Within PjBL

The learning model was Project Based Learning, and the project was the production of ecobricks, which are plastic bottles densely filled with non-organic plastic waste so that they can be reused as functional objects. The project was selected because plastic waste is a problem that students encounter in daily life, the materials are simple and available around them, and the activity can integrate reading, writing, and speaking. The PjBL stages were adapted as follows: determining essential questions, project planning, schedule arrangement, project implementation and monitoring, testing the results, and evaluating the experience. Within the project, students read information about the impact of plastic waste and the process and benefits of making ecobricks, wrote systematic reports from the preparation stage to the final product, and presented their results to the class.

Figure 2 presents the ecobrick learning media used in the project, consisting of a plastic bottle densely filled with plastic waste. Students produced, tested, and presented this product during the learning activities.



Figure 2. Ecobrick learning media

Figure 2 shows the ecobrick product made from plastic waste. The product was assessed according to density, neatness, and functionality criteria.

The activity schedule followed the PjBL syntax, and each cycle used one meeting of two lesson hours of 35 minutes each. The initial activities introduced plastic waste and ecobricks through reading and discussion, followed by project planning and implementation, including material collection and ecobrick making. The final activities covered project completion, written reports, and presentations. The teacher adjusted time flexibly when materials were limited or when students' learning pace varied, so that all students could take part in each stage.

Tables 1 and 2 summarize the learning instruments and implementation procedures used in Cycle I and Cycle II. The lesson plan and environmental literacy observation sheet remained in use across both cycles, while the worksheet format, group arrangement, activity location, and problem stimulus were revised in Cycle II.

Table 1. Learning instruments used in Cycle I and Cycle II

Learning instrument	**Cycle I**	**Cycle II**
Lesson plan	Used	Used
Student worksheet (*Lembar Kerja Peserta Didik*, LKPD): large-group practice with partial steps	Used	Not used
Student worksheet (LKPD): small-group practice with complete steps	Not used	Used
Environmental literacy observation sheet	Used	Used

Table 2. Comparison of the implementation of actions in Cycle I and Cycle II

Aspect	**Cycle I**	**Cycle II**
Duration	1 meeting (2 lesson hours)	1 meeting (2 lesson hours)
Location of activities	Inside the classroom	Inside and outside the classroom

Learning model	PjBL with large groups	PjBL with small groups
Problem stimulus	Infographics from the internet	Direct observation of the surrounding environment
Closing measure	Cycle I posttest	Cycle II posttest

Table 1 shows that the lesson plan and environmental literacy observation sheet were used in both cycles, while the worksheet changed from large-group practice with partial steps to small-group practice with complete steps. Table 2 shows that the duration remained constant, while the activity location, group size, and problem stimulus changed between cycles. Because several features changed simultaneously, the improvement observed in Cycle II cannot be attributed to any single modification.

Instruments and Data

The data were quantitative test scores and descriptive teacher observations recorded with the environmental literacy observation sheet. The test contained five multiple-choice items and five short-answer items related to the "Love the Environment" material. The items referred to three indicators, in line with the multidimensional frameworks reviewed by McBride et al. (2013): the cognitive indicator covered knowledge, analytical ability, and problem solving; the affective indicator covered attitudes, appreciation, and motivation to behave in environmentally friendly ways; and the behavioral indicator covered the ability to implement concepts through real actions. The pretest, the Cycle I posttest, and the Cycle II posttest used the same questions and the same test duration.

Tables 3 and 4 present the structure and scoring of the environmental literacy test and the criteria used to classify normalized gain. The test comprised 10 items with a maximum raw score of 30, while normalized gain was classified as high, moderate, or low according to the thresholds specified in Table 4.

Table 3. Structure and scoring of the environmental literacy test

Component	Number of items	Points per correct answer	Maximum points
Multiple-choice items	5	2	10
Short-answer items	5	4	20
Total	10	-	30

Note. Incorrect answers received 0 points. Total scores were expressed on a 0–100 scale for reporting.

Table 4. Normalized gain criteria

Normalized gain (g)	Category
$g \geq 0.70$	High
$0.30 \leq g < 0.70$	Moderate
$g < 0.30$	Low

Note. Criteria follow Hake (1998).

Table 3 shows that the test contained five multiple-choice items worth two points each and five short-answer items worth four points each. Table 4 defines high normalized gain as $g \geq 0.70$, moderate gain as $0.30 \leq g < 0.70$, and low gain as $g < 0.30$, following Hake (1998).

Data Analysis

Test responses were scored with 2 points for each correct multiple-choice answer, 4 points for each correct short-answer response, and 0 points for incorrect answers, and total scores were expressed on a 0 to 100 scale. Individual mastery was defined as a score of at least 75, which is the school's *Kriteria Ketuntasan Minimal* (Minimum Mastery Criterion, KKM), and classical mastery was defined as at least 85% of students reaching the KKM. Improvement was analyzed with normalized gain, g = (posttest score − pretest score) / (maximum score − pretest score), as formulated by Hake (1998), and Coletta and Steinert (2020) argued that this index remains appropriate for analyzing pre-instruction and post-instruction scores. Following Meltzer (2002), who reported that conceptual gains can vary with students' prior preparation, gains were interpreted alongside pretest levels, and only descriptive statistics were used because the study involved a single class of 23 students.

RESULTS

This section reports the results of the pretest, Cycle I, and Cycle II in the order of mean scores, learning mastery, normalized gain, and observed learning processes. Before the intervention, observations and a brief interview with the classroom teacher indicated that students' environmental literacy was low and that environmental values had not yet been applied in daily situations. The pretest results were consistent with this observation, with a mean score of 36.22 and only 30.43% of students reaching the Minimum Mastery Criterion. All results below are descriptive and refer to the 23 students in the class.

Mean Scores

Table 5 and Figure 3 present the mean environmental literacy scores at the pretest, Cycle I, and Cycle II, together with the increase from the pretest and the class-level normalized gain. The mean score increased from 36.22 at pretest to 64.78 in Cycle I and 84.74 in Cycle II, while the class-level normalized gain increased from 0.45 to 0.76.

Table 5. Mean environmental literacy scores and class-level normalized gain (N = 23)

Measurement point	Mean score	Increase from pretest	Class-level normalized gain	Category
Pretest	36.22	-	-	-
Cycle I	64.78	+28.56	0.45	Moderate
Cycle II	84.74	+48.52	0.76	High

Note. Class-level normalized gain = (mean posttest − mean pretest) / (100 − mean pretest).

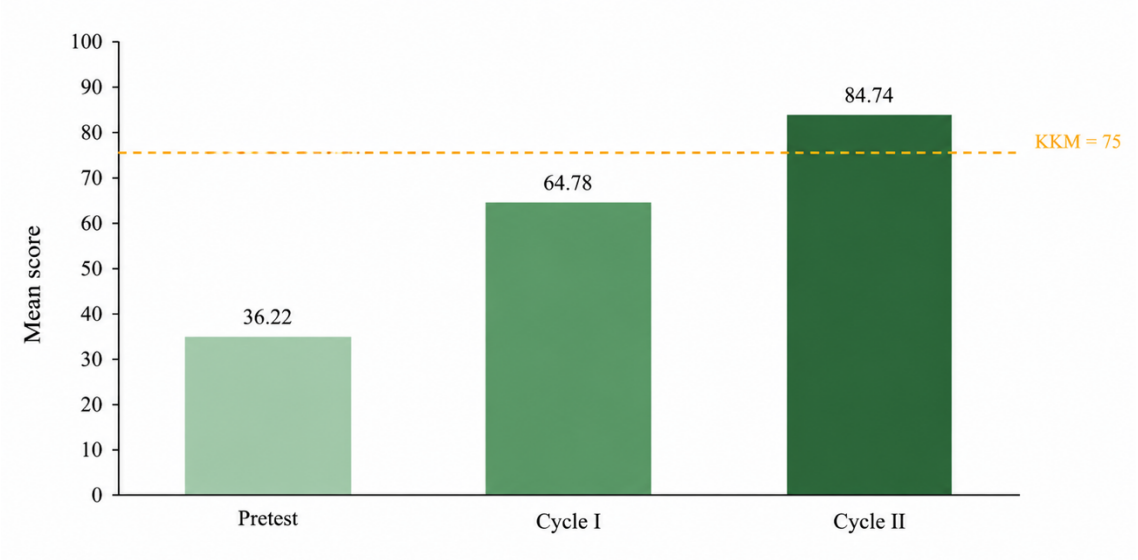


Figure 3. Comparison of mean environmental literacy scores in the pretest, Cycle I, and Cycle II

The mean score increased by 28.56 points from the pretest to Cycle I and by a further 19.96 points from Cycle I to Cycle II, giving a total increase of 48.52 points. The class-level normalized gain was 0.45 in Cycle I, within the moderate category, and 0.76 in Cycle II, within the high category. The Cycle II mean of 84.74 exceeded the Minimum Mastery Criterion of 75, whereas the Cycle I mean of 64.78 remained below the criterion.

Learning Mastery

Table 6 and Figure 4 present the number and percentage of students who met the Minimum Mastery Criterion of 75 at each measurement point. The classical mastery standard was set at 85% of students reaching the criterion.

Table 6. Individual and classical mastery (N = 23)

Measurement point	Mastery achieved, n (%)	Mastery not yet achieved, n (%)	Classical mastery (≥ 85%)
Pretest	7 (30.43)	16 (69.57)	Not achieved
Cycle I	17 (73.91)	6 (26.09)	Not achieved
Cycle II	21 (91.30)	2 (8.70)	Achieved

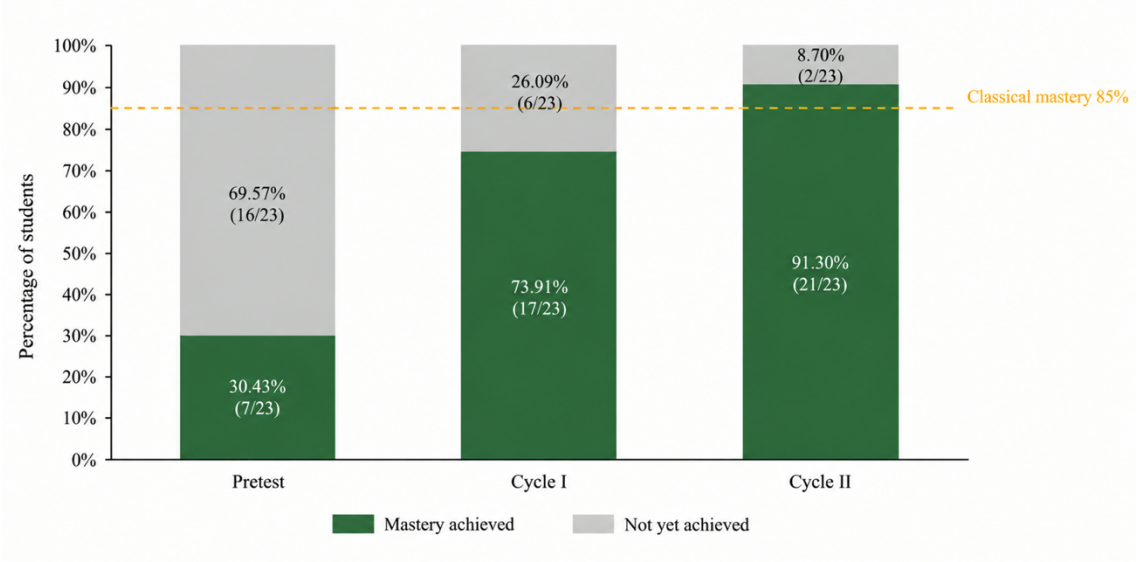


Figure 4. Individual mastery of students in the pretest, Cycle I, and Cycle II

At the pretest, 7 students (30.43%) had reached mastery and 16 students (69.57%) had not, which indicates that most students lacked adequate environmental literacy before the intervention. After Cycle I, mastery rose to 17 students (73.91%) and the number of students below the criterion fell to 6 (26.09%), a level that remained under the 85% classical standard. After Cycle II, 21 students (91.30%) reached mastery and 2 students (8.70%) remained below the criterion, so the classical mastery standard was met. These figures show that improvement in the class mean was accompanied by a reduction in the number of students left below the criterion, and the 2 remaining students are candidates for targeted follow-up.

Normalized Gain

Table 7 and Figure 5 present the distribution of students across normalized gain categories in Cycle I and Cycle II. Individual gains were classified as high, moderate, or low using the criteria specified in Table 4.

Table 7. Distribution of students by normalized gain category (N = 23)

Category	Cycle I, n (%)	Cycle II, n (%)
Low	9 (39.13)	0 (0.00)
Moderate	8 (34.78)	7 (30.43)
High	6 (26.09)	16 (69.57)
Total	23 (100.00)	23 (100.00)

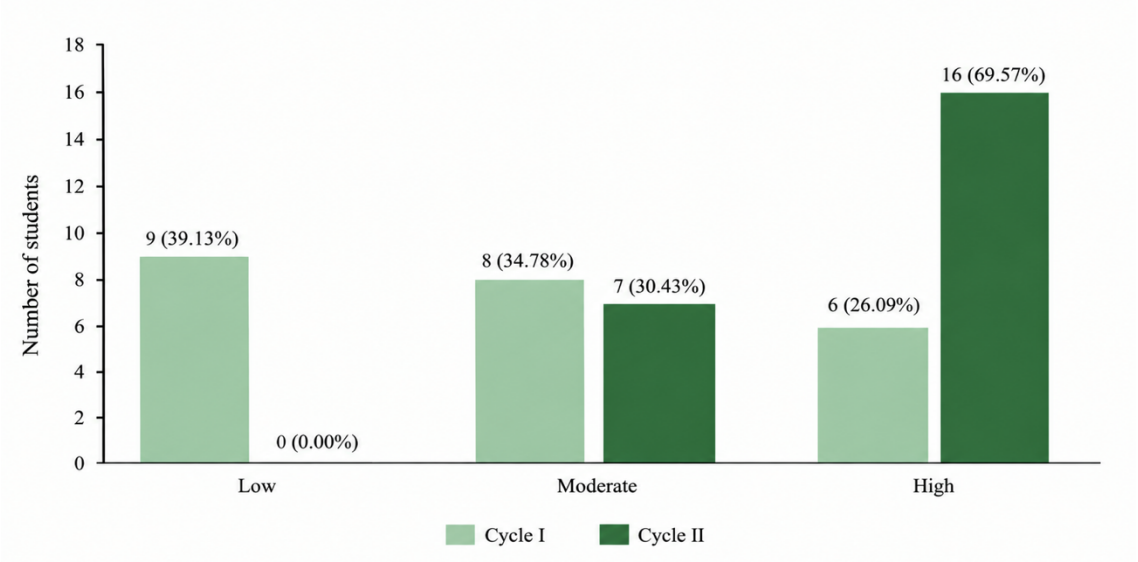


Figure 5. Distribution of students by normalized gain category in Cycle I and Cycle II

In Cycle I, 9 students (39.13%) were in the low category, 8 students (34.78%) in the moderate category, and 6 students (26.09%) in the high category. In Cycle II, 16 students (69.57%) were in the high category, 7 students (30.43%) in the moderate category, and no student remained in the low category. All students therefore achieved at least a moderate gain in Cycle II, and the largest category changed from low in Cycle I to high in Cycle II. These results are relevant for judging whether the revisions made after Cycle I reached students who had benefited little in the first cycle.

Learning Process and Project Products

Table 8 summarizes the teacher's observations of student participation, collaboration, reading, writing, speaking, and ecobrick products across the two cycles. The observations provide descriptive information about classroom processes accompanying the changes in test scores.

Table 8. Summary of teacher observations of the learning process and project products

Aspect	Observation
Participation (Cycle I, large groups)	Several students were passive and lacked confidence in expressing their opinions.
Participation (Cycle II, small groups)	Participation increased, and students were more active in discussions and problem solving.
Collaboration	Students worked together more effectively in small groups and were more confident in asking questions.
Reading	Students read information more carefully.
Writing	Students wrote observation results more systematically and prepared simple reports containing objectives, tools and materials, procedures, and results.
Speaking	Students presented discussion outcomes orally in a clearer manner and explained the processes they carried out.
Ecobrick products	Most students produced ecobricks that met the criteria of density, neatness, and functionality.

The observations indicate that participation was uneven in Cycle I and increased after the class was divided into small groups in Cycle II. Students read information more carefully, wrote observation results more systematically, and presented discussion outcomes more clearly. Most ecobricks met the criteria of density, neatness, and functionality. Because these observations were recorded by the teacher without a second rater, they should be interpreted as descriptive evidence of classroom processes.

DISCUSSION

Changes in Environmental Literacy Scores and Learning Mastery

The main finding of this study is that mean environmental literacy scores rose from 36.22 in the pretest to 64.78 in Cycle I and 84.74 in Cycle II, while the proportion of students reaching the Minimum Mastery Criterion increased from 30.43% to 91.30%. This pattern may be associated with the combination of an observable plastic waste problem, a hands-on product, and repeated refinement of the learning arrangement. These components provided students with opportunities to engage with environmental concepts through information gathering, observation, discussion, and ecobrick production. Baierl et al. (2021) reported knowledge gains and shifts in pro-environmental attitudes among 6,585 fourth- to sixth-grade students following a three-day outdoor earth education program. The upward trend in the present study is consistent with the broader finding that structured environmental learning experiences can support students' environmental knowledge and attitudes. However, the current results represent improvement within one class across two cycles of instruction and should be interpreted in that context.

The improvement in learning mastery is also relevant to the use of project-based learning (PjBL) in the early grades. Viñuela and de Caso Fuertes (2022) studied 77 pre-school children and reported that active methodologies, including project-based and cooperative learning, were associated with intrinsic motivation toward teaching and learning. Dole et al. (2016), based on interviews with 36 teachers who facilitated problem-based and project-based learning during a field experience, reported changes in teachers' pedagogy toward learner-centered practice. These studies provide contextual support for the use of active learning tasks, although their participants and research settings differ from those of the present study. In this study, students worked with a familiar environmental issue and created a tangible product, which may have helped connect environmental concepts with classroom activities. The findings indicate that ecobrick-based PjBL can be implemented as an approach to environmental learning in the early grades, while further research is needed to determine the extent to which the observed gains can be attributed to the intervention.

Distribution of Students Across Normalized Gain Categories

The distribution of normalized gain shifted between the two cycles. In Cycle I, 39.13% of students were in the low-gain category, whereas no students remained in that category in Cycle II. By Cycle II, 69.57% of students were in the high-gain category. This pattern indicates that score improvements occurred across the class and that a larger proportion of students achieved high normalized gains during the second cycle. The change

coincided with revisions to the learning arrangement following reflection on Cycle I, including smaller groups and a change in the problem stimulus. These revisions may have provided students with more opportunities to participate and engage directly with the environmental issue. Nevertheless, because several instructional features changed between cycles, the gain distribution cannot establish the separate contribution of each revision.

The findings also highlight the importance of considering students' starting points when interpreting normalized gain. Bølling et al. (2018) found that improvements in intrinsic motivation associated with regular education outside the classroom were moderated by students' prior intrinsic motivation, suggesting that students may respond differently to the same learning context. Dole et al. (2016) similarly reported that facilitating project-based learning could shift teachers toward learner-centered practice, emphasizing the role of instructional decisions in supporting student engagement. In the present study, the shift in gain categories may indicate that the revisions introduced in Cycle II provided a more supportive learning arrangement for the class. However, the study did not isolate the effects of group size, problem stimulus, or other instructional components. The category distribution is therefore best interpreted as descriptive evidence of learning improvement across the cycles and as a basis for planning further instructional refinement.

Group Arrangement, Problem Stimulus, and Student Participation

The changes in group arrangement and problem stimulus between cycles coincided with improvements in students' participation and environmental literacy scores. In Cycle II, the class was divided into smaller groups, and the teacher reported increased participation, more careful reading, more systematic recording of observations, and clearer presentations of group findings. Smaller groups may have created more opportunities for individual students to speak, handle materials, and contribute to a shared task. This interpretation is compatible with Bølling et al. (2019), who examined pupils aged 9 to 13 and reported that regular education outside the classroom was positively associated with gains in new peer affiliations. However, the same study found no increase in the total number of relationships and described the positive changes as minor. These findings suggest that opportunities for interaction may depend on how group activities are organized and how students participate within them.

The problem stimulus also changed from infographics in Cycle I to direct observation of the school surroundings in Cycle II. This shift may have helped students connect information about plastic waste with visible conditions in their immediate environment. Research on outdoor education has reported associations with improved intrinsic motivation (Bølling et al., 2018) and a steadier decline in cortisol during the school day among children who attended a forest-based learning program once a week (Dettweiler et al., 2017). Yue and Chen (2023) also reported that the relationship between nature connection and conservation behavior among preadolescents was influenced by location and residence type. These studies provide context for considering how learning environments may shape students' experiences, although their settings differ from

observation within a school yard. Evidence from 495 California elementary schools linking tree and shrub cover in school surroundings with school performance further suggests that everyday school environments may be educationally relevant (Tallis et al., 2018). In this study, the contributions of group size and problem stimulus cannot be separated because both were revised between cycles. Future studies could vary these features independently to examine their respective relationships with participation and environmental literacy.

Environmental Literacy Across Cognitive, Affective, and Behavioral Indicators

The environmental literacy test combined cognitive, affective, and behavioral indicators, and the increase in total scores suggests that students improved in their responses across the assessed domains. The ecobrick project provided a learning context in which students encountered information about plastic waste and participated in a practical activity related to waste reuse. Liefländer and Bogner (2018) monitored environmental attitudes and three dimensions of environmental knowledge among 133 fourth-graders during a four-day field centre program. They reported that a stronger utilization attitude was associated with lower environmental knowledge across dimensions. Their findings illustrate that environmental attitudes and knowledge can have complex relationships and should be considered carefully when interpreting environmental literacy. Baierl et al. (2024), analyzing a sample of 1,486 students, found that attitude toward nature determined the levels of knowledge students gained and retained. This suggests that written test scores may not fully represent the affective processes involved in environmental learning.

The relationship between environmental understanding and behavior is also important when students engage in practical environmental projects. Barrera-Hernández et al. (2020) surveyed 296 children with an average age of 10.42 years and reported that connectedness to nature was related to sustainable behaviors, which were in turn related to happiness. This evidence supports the educational relevance of learning experiences that connect environmental issues with concrete actions. In the present study, making ecobricks gave students an opportunity to handle plastic waste and consider a possible reuse of the material. However, the study did not separately measure changes in environmental attitudes, actual waste-sorting practices, or littering behavior. The observed increase in total test scores should therefore be interpreted as evidence of improvement in the assessed environmental literacy outcomes, while the extent of change in students' everyday environmental behavior remains to be established through direct behavioral measures.

Environmental Literacy Development and Related Literacy Skills

Teacher observations indicated that students read information more carefully, recorded observation results more systematically, and presented their findings more clearly during the learning activities. These observations suggest that environmental project work provided opportunities to practice reading, writing, and speaking while students explored an environmental issue. Such integration may be valuable in the early grades, where environmental learning can be connected with broader literacy development. Duke et al. (2021), in a randomized trial involving second-grade students, found higher growth in

social studies and informational reading under PjBL, although they found no corresponding difference in writing or motivation. The results provide relevant evidence that project-based instruction can support some literacy outcomes, while also indicating that the effects may differ across skills and measures.

The teacher-reported improvements in writing and presentation in the present study should be interpreted cautiously because these skills were not measured using dedicated literacy instruments. Otte et al. (2019) used a comparison group and detected a small positive association between regular education outside the classroom and reading performance. Their design differs from the present classroom-based study, which relied on teacher observations and did not include a comparison group. Consequently, the observed changes in reading, writing, and speaking provide descriptive evidence of classroom processes rather than a separate estimate of literacy development. Future research could examine environmental literacy and general literacy outcomes using validated reading and writing assessments, presentation rubrics, and direct observations of student participation. Such measures would help determine whether environmental project work contributes to the development of literacy skills alongside students' understanding of environmental issues.

Ecobrick Projects and Practical Environmental Awareness

The ecobrick project connected classroom learning to a plastic waste problem that students could observe and handle. According to the teacher's observations, most products met the criteria for density, neatness, and functionality. Producing the ecobricks gave students a practical task through which they could discuss plastic waste and consider how discarded materials might be reused. Lau et al. (2020) modeled global plastic flows and estimated that even with immediate and concerted action, 710 million metric tons of plastic waste would cumulatively enter aquatic and terrestrial ecosystems between 2016 and 2040. This global context underscores the significance of addressing plastic waste through environmental education. At the school level, ecobrick production can serve as an entry point for discussing waste management and material reuse, although producing ecobricks alone does not address the broader systems of plastic production, consumption, and disposal.

The practical nature of the project may also create opportunities for extending environmental learning into other subject areas. For example, students in later grades could compare the density of bottles filled to different levels, record measurements, and discuss the properties of the resulting products. These activities could connect environmental awareness with mathematics and scientific investigation. Regmi et al. (2020) reported that most of 379 rural Nepalese children aged 11 to 16 held pro-environmental values. The present study adds a classroom-level example from an Indonesian primary school in which students engaged with plastic waste through a structured project. However, the study did not directly measure whether students continued to reuse materials, sort waste, or change their environmental practices outside the classroom. The educational value of ecobrick projects should therefore be considered

in relation to both students' learning experiences and the need to evaluate whether these experiences translate into sustained environmental action.

Limitations and Directions for Future Research

Several limitations should be considered when interpreting the findings. First, the study involved one class of 23 students without a comparison group, which limits the generalizability of the results and prevents the observed improvements from being attributed to the intervention alone. Second, the same test was used at all three measurement points. Repeated exposure to the test may have contributed to score gains, so the changes cannot be interpreted solely as evidence of learning attributable to the instructional approach. Third, the teacher acted as both instructor and observer, and the classroom observations were not independently verified by a second rater. These conditions limit the extent to which the observed changes in participation, collaboration, and literacy-related activities can be treated as independently corroborated outcomes.

Future studies could address these limitations by involving comparison groups, using equivalent test forms across measurement points, and administering a delayed posttest to examine the persistence of learning gains. Indicator-level scoring could also clarify whether cognitive, affective, and behavioral dimensions of environmental literacy change in similar ways. Inferential statistics and suitable effect-size estimates would provide additional information about the magnitude and uncertainty of the observed changes. In addition, independent observers and structured behavioral measures could be used to assess participation, littering, and waste-sorting practices. Researchers could also vary group arrangement and problem stimulus separately to examine their respective relationships with learning outcomes. These steps would strengthen the evidence concerning the implementation of ecobrick-based PjBL and its potential contribution to environmental literacy in the early grades.

CONCLUSION

The results answer the first research question by showing that mean scores rose from 36.22 to 64.78 and then to 84.74, and that learning mastery increased from 30.43% to 73.91% and then to 91.30%, which met the classical mastery standard in Cycle II. For the second research question, the distribution of normalized gain shifted from 39.13% of students in the low category in Cycle I to no students in the low category and 69.57% in the high category in Cycle II. For the third research question, the teacher observed greater participation and more positive literacy behaviors after the move to small groups and direct observation, although the contribution of each change could not be separated. These findings suggest that ecobrick-based PjBL is a feasible approach for improving environmental literacy in the early grades, and future research with comparison groups, delayed posttests, and behavioral measures is needed to examine the durability of the improvement.

AI Use Statement

AI-assisted tools were used, where applicable, for language refinement and proofreading. The authors reviewed the manuscript and take responsibility for its content.

Author Contributions

NA: conceptualization, research design, data collection, data analysis, and initial manuscript preparation. NY: research methodology, supervision of classroom implementation, data interpretation, and manuscript revision. E: classroom implementation, observation, and data collection. MRBH: critical review, interpretation of findings, and manuscript editing. All authors approved the final manuscript.

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Conflict of Interest

The authors declare no competing interests.

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