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Project-Based Learning in Science Education Utilizing Household Waste to Enhance Students' Environmental Literacy and Scientific Skills

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Abstract

Household waste is a familiar environmental issue that can be transformed into a meaningful context for science learning. This article examines how Project-Based Learning (PjBL) using household waste can be designed to support students' environmental literacy and scientific skills. It adopts a literature-based conceptual approach by synthesizing scholarship on project-based learning, environmental literacy, science inquiry, and waste management. The proposed learning sequence begins with a local waste audit, proceeds through classification and investigation of material properties and decomposition, and culminates in the design, testing, and communication of a practical waste-reduction or reuse product. The synthesis indicates that the educational value of this approach lies in connecting scientific concepts with authentic problems, providing opportunities for collaborative inquiry, and requiring students to use evidence when explaining and evaluating solutions. Environmental literacy can be addressed through students' knowledge, concern, attitudes, and action-oriented decision-making, while scientific skills can be developed through observing, measuring, classifying, formulating questions, interpreting data, drawing conclusions, and communicating findings. These outcomes depend on careful scaffolding, safe material selection, explicit assessment criteria, and reflection on the limits of recycling. The article offers a design framework for teachers; its proposed effects require validation through classroom implementation and empirical assessment.

Keywords

Environmental literacy; household waste; Project-Based Learning; science education; scientific skills

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INTRODUCTION

Environmental challenges increasingly require citizens who can understand ecological processes and make informed decisions about everyday consumption and waste. Household waste is particularly suitable for science education because it is generated in familiar settings and contains materials with different physical, chemical, and biological characteristics. Food scraps, paper, packaging, plastics, glass, and metal can become observable learning resources through which students investigate material properties, decomposition, resource use, pollution pathways, and waste prevention. The United Nations Environment Programme (UNEP, 2021) emphasizes that plastic pollution is persistent and that a substantial share of marine litter originates from inadequately managed land-based waste. Such challenges demonstrate why environmental learning should move beyond memorizing environmental terms toward examining the consequences of human practices.

Science education is expected to develop the ability to use scientific knowledge, evidence, and inquiry processes to interpret phenomena and solve problems. The National Research Council (2012) describes science learning as the integration of scientific and engineering practices, crosscutting concepts, and disciplinary core ideas. In a similar direction, the Next Generation Science Standards Lead States (2013) emphasize asking questions, planning investigations, analyzing data, constructing explanations, and designing solutions. Household waste projects provide a context for these practices: students can measure the composition of waste, compare decomposition conditions, test the strength or usefulness of reused materials, and justify recommendations using evidence.

Project-Based Learning (PjBL) is a student-centered approach organized around an authentic question or problem and a sustained process of investigation, creation, and presentation. Bell (2010) explains that project work can support collaboration, communication, critical thinking, and problem solving. Thomas (2000) similarly identifies central design features of project-based learning, including a central question, constructive investigation, and learner autonomy. Condliffe (2017) highlights the importance of implementation quality and alignment between project activities and learning goals. Kokotsaki et al. (2016), in their review, identify student autonomy, constructive investigation, goal setting, collaboration, communication, and reflection as central features of PjBL. In science education, this structure can connect abstract concepts with observable phenomena and tangible products. However, projects do not automatically produce deep learning; teachers need to scaffold inquiry, align assessment with learning objectives, and ensure that the final product does not

replace scientific reasoning.

Environmental literacy is broader than awareness or factual knowledge. It includes the capacity to understand environmental systems, recognize human-environment relationships, evaluate information, develop concern, and make decisions or take actions that contribute to environmental quality. Roth (1992) presents environmental literacy as a continuum from basic awareness to more developed competence and action. McBride et al. (2013) discuss environmental literacy as a multidimensional construct that includes knowledge, dispositions, competencies, and environmentally responsible behavior. Hollweg et al. (2011) likewise provide a framework for assessing environmental literacy across knowledge, affect, skills, and behavior. Accordingly, a household-waste project should assess not only what students know but also how they investigate, reason, evaluate alternatives, and translate learning into responsible practices.

Scientific skills in this article refer to the processes students use to generate and evaluate evidence, including observing, measuring, classifying, predicting, questioning, planning fair tests, recording data, interpreting patterns, drawing conclusions, and communicating explanations. These skills are consistent with the inquiry-oriented view of science learning articulated by the National Research Council (2012). By engaging with real waste materials, students can practice these processes in a concrete setting rather than treating science as a collection of disconnected facts.

Although PjBL, environmental education, and waste-management education have each been widely discussed, teachers still need practical models that integrate household waste as a local learning resource while addressing both environmental literacy and scientific skills. This article therefore develops a conceptual learning framework for science education based on household waste. It focuses on the alignment between project stages, scientific practices, environmental-literacy dimensions, and assessment evidence. As no primary classroom data were supplied, the article does not claim measured learning gains; instead, it synthesizes literature and proposes an instructional design for subsequent empirical testing.

METHODS

This article uses a qualitative, literature-based conceptual review. It draws on foundational and contemporary publications concerning project-based learning, science inquiry, environmental literacy, environmental education, and solid-waste management. The sources were selected for their conceptual relevance to (1) the characteristics and implementation of PjBL, (2) the dimensions and assessment of

environmental literacy, (3) scientific and inquiry skills, and (4) the environmental significance of household waste. The synthesis is narrative rather than a systematic review or meta-analysis; therefore, it does not claim exhaustive coverage of all available studies or calculate a pooled effect size.

The analysis was conducted thematically. First, key concepts were identified from the literature. Second, the concepts were grouped into instructional principles, project stages, intended student competencies, and assessment approaches. Third, these categories were aligned to construct a proposed household-waste PjBL framework. The framework is intended as a design proposition that teachers may adapt to students' age, curriculum, school facilities, and local waste-management conditions. Any classroom use should comply with school safety procedures and local waste-handling rules.

The conceptual framework links an authentic local problem to an inquiry-and-design cycle. Students investigate household waste, formulate questions, collect and analyze evidence, develop a feasible intervention, test or evaluate it, and communicate their findings. Environmental literacy and scientific skills are developed through overlapping activities rather than isolated lessons.

RESULTS AND DISCUSSION

Results

The literature synthesis produced four connected design principles. First, the project should begin with a recognizable environmental problem, such as the amount and types of waste produced at home or school. Second, students should engage in structured scientific inquiry rather than simply making decorative objects from discarded materials. Third, the project should include a decision-making component in which students compare prevention, reduction, reuse, sorting, and recycling options. Fourth, assessment should examine both the quality of scientific processes and the environmental reasoning demonstrated by students. These principles are summarized in Table 1.

Table 1. Proposed Project-Based Learning Sequence Using Household Waste

Stage	Main learning activity	Scientific skills	Environmental-literacy focus
1. Problem orientation	Identify a local waste issue and formulate a driving	Asking questions; observing; identifying	Awareness of waste sources and consequences

	question	variables	
2. Waste audit and classification	Record, weigh, and categorize household or classroom waste	Measuring; classifying; tabulating data	Knowledge of waste composition and consumption patterns
3. Investigation	Examine material properties, decomposition, or reuse possibilities	Predicting; planning tests; recording observations	Understanding material life cycles and environmental impacts
4. Design and action	Develop a waste-reduction, reuse, or sorting solution	Designing; selecting evidence; problem solving	Evaluating alternatives and responsible decision-making
5. Testing and revision	Test product or intervention against agreed criteria	Measuring; comparing; interpreting data	Reflecting on effectiveness and limitations
6. Presentation and reflection	Present evidence, recommendations, and personal or group commitments	Communicating; arguing from evidence; drawing conclusions	Responsible action and environmental participation

Source: Authors' conceptual synthesis based on the literature reviewed.

A possible driving question is: "How can our class reduce the amount of household waste that is sent for disposal while using scientific evidence to choose effective actions?" The question is sufficiently open to allow students to investigate different waste streams, but it also provides a clear direction for inquiry. Groups may focus on food waste, paper, plastic packaging, or mixed household waste. The choice should reflect local conditions and avoid hazardous, contaminated, sharp, or otherwise unsuitable materials.

Discussion

Connecting scientific concepts with everyday waste

Household waste offers a concrete context for teaching matter, material properties, ecosystems, decomposition, and resource cycles. Students can compare absorbency, flexibility, durability, density, or water resistance of selected clean materials, depending on the curriculum and available equipment. They may also investigate how

environmental conditions influence the decomposition of biodegradable materials using safe, teacher-supervised procedures. These activities support conceptual understanding when students are required to explain observations using scientific ideas. Opportunities to connect with local environments and reflect on environmental change may also support constructive hope and meaningful engagement (Chawla, 2020). A project that only produces a recycled craft, without investigation or explanation, has limited potential to develop scientific reasoning.

PjBL can strengthen the relationship between knowledge and practice because learners work toward a meaningful outcome while engaging in investigation and collaboration. Bell (2010) highlights the relevance of project work to skills needed for contemporary learning, while Kokotsaki et al. (2016) emphasize the importance of teacher guidance, effective group processes, reflection, and aligned assessment. The review by Kurt and Akoglu (2023) also identifies PjBL as an approach used in science education and discusses its effects, implementation opportunities, and challenges. These sources support the rationale for PjBL, but they do not establish that every household-waste project will produce the same outcomes in every school context.

Developing environmental literacy through informed decisions

A central contribution of the proposed design is the opportunity to move from environmental awareness to evidence-informed decision-making. During a waste audit, students identify the kinds and quantities of waste produced. They can then consider why certain materials are used, whether they can be avoided, and what happens after disposal. This process makes the connection between personal consumption, waste systems, and environmental consequences visible. UNEP (2021) documents the scale and persistence of plastic pollution, while Kaza et al. (2018) show that municipal solid-waste generation and management are major global development concerns. These reports provide a real-world basis for discussing why waste prevention and responsible management matter.

Environmental literacy should not be reduced to the ability to name recyclable materials. Research on environmental education outcomes also points to the importance of evaluating knowledge, attitudes, skills, and behavior rather than relying on a single awareness measure (Ardoin et al., 2020). Students need to compare options and recognize that recycling is only one component of responsible waste management. Prevention and reduction may avoid material use in the first place; reuse can extend product life; and recycling depends on appropriate sorting, infrastructure, and processing. The waste hierarchy provides a useful basis for discussing these choices (European Parliament and Council, 2008). Students should therefore be encouraged to

justify why a proposed action is appropriate for their local context rather than assuming that all waste can or should be recycled.

The dimensions proposed by Roth (1992), McBride et al. (2013), and Hollweg et al. (2011) suggest a multidimensional assessment approach. Knowledge can be assessed through explanations of waste pathways and material properties. Dispositions can be explored through students' expressed concern and willingness to consider alternatives. Competencies can be assessed through the ability to interpret waste-audit data and evaluate solutions. Behavior can be examined through documented actions or follow-up observations, while recognizing that short-term classroom projects cannot by themselves establish lasting behavioral change.

Strengthening scientific skills through evidence-based inquiry

The project sequence provides repeated opportunities for students to practice scientific skills. During the waste audit, they observe, sort, count, weigh, and record materials using consistent categories. During investigation, they formulate testable questions, identify variables, and decide what evidence is needed. During analysis, they organize data in tables or graphs, compare patterns, and consider possible sources of error. During presentation, they use evidence to support claims and acknowledge limitations. These processes align with the scientific and engineering practices emphasized by the National Research Council (2012) and the Next Generation Science Standards Lead States (2013). Bybee (2014) also explains the value of structuring science instruction around engagement, exploration, explanation, elaboration, and evaluation.

Assessment should make the reasoning process visible. For example, a group investigating paper reuse could record the mass of paper collected over a defined period, compare the amount reused with the amount discarded, and explain how the measurement was made. A group exploring food waste could categorize leftovers and examine possible causes, without handling spoiled food. Students should distinguish observation from inference, report units accurately, and avoid claiming that a small classroom sample represents an entire community. Such expectations help develop scientific habits of accuracy, transparency, and evidence-based argument.

Teacher scaffolding and inclusive project design

The teacher's role is to structure the project so that student autonomy is balanced with sufficient guidance. Teachers can provide a project timeline, safety rules, data-recording templates, criteria for evaluating sources, and checkpoints for reviewing research questions and evidence. Group roles—such as coordinator, recorder,

materials manager, and presenter—can support participation, although roles should rotate so that all students experience different tasks. Kokotsaki et al. (2016) note that teacher scaffolding and well-managed group processes are important conditions for effective PjBL implementation.

Projects should be feasible, inclusive, and safe. Students should use clean and non-hazardous materials only; they should not handle medical waste, batteries, chemical containers, broken glass, sharp metal, or contaminated organic waste. Food-waste investigations should be designed to avoid exposure to spoiled materials. Teachers should consider students' access to materials at home and avoid requiring families to purchase supplies. A school-based waste audit can provide an equitable alternative when household participation is impractical.

Assessment framework and implementation considerations

A balanced assessment plan can combine a short concept test, an inquiry-process rubric, an environmental-literacy reflection, a project product evaluation, and a presentation rubric. The concept test can assess knowledge of material properties and waste pathways. The inquiry rubric can assess question formulation, measurement, data quality, analysis, and conclusions. The environmental-literacy reflection can ask students to explain the environmental significance of their findings and defend a practical action. Product evaluation should consider usefulness, safety, durability, resource efficiency, and whether the product addresses the original problem. Assessment criteria should be shared before project work begins.

Table 2. Suggested Assessment Dimensions and Evidence

Dimension	**Indicators**	**Possible evidence**
Environmental knowledge	Explains waste categories, material properties, and environmental pathways	Concept map; written explanation; quiz
Environmental disposition	Demonstrates concern and considers consequences of consumption	Reflection journal; discussion record
Environmental competence	Evaluates alternatives and proposes context-appropriate action	Decision matrix; project proposal
Responsible action	Documents feasible waste-reduction or sorting	Action log; follow-up observation

	practices	
Scientific process skills	Observes, measures, classifies, analyzes data, and communicates conclusions	Lab sheet; data table; graph; presentation

Source: Authors' proposed assessment framework, informed by Roth (1992), Hollweg et al. (2011), and McBride et al. (2013).

Several implementation challenges should be anticipated. Time constraints may limit repeated measurement and revision; insufficient tools may affect the reliability of data; and students may focus on the appearance of a product rather than the science behind it. These risks can be reduced by narrowing the driving question, selecting accessible materials, using simple standardized measurement procedures, and requiring an evidence-based explanation alongside the final product. Teachers should also discuss the limitations of small-scale reuse projects: a classroom product does not necessarily solve the wider problem of packaging consumption or municipal waste management.

The proposed framework is consistent with broader environmental-education goals that connect knowledge, values, skills, and participation. UNESCO (2020) emphasizes education for sustainable development as a means of equipping learners with knowledge, skills, values, and attitudes to make informed decisions. The household-waste project translates this broad aim into a local science-learning experience. UNESCO (2017) identifies learning objectives related to knowledge, skills, values, and attitudes across the Sustainable Development Goals, while OECD (2019) underscores the importance of applying knowledge to real-world contexts. Nevertheless, the framework remains a conceptual proposal. Future classroom research should test it using clearly defined participants, a validated environmental-literacy instrument, scientific-skills rubrics, pre- and post-assessments where appropriate, and transparent reporting of implementation conditions.

CONCLUSION

Project-Based Learning using household waste offers a practical way to connect science concepts with an environmental issue that students encounter in daily life. A well-designed project can integrate waste auditing, material investigation, data analysis, solution design, testing, and communication. These activities provide opportunities to address environmental literacy through knowledge, dispositions, competencies, and responsible action, while developing scientific skills such as observing, measuring, classifying, interpreting evidence, and communicating

conclusions. The educational value depends on inquiry and evidence, not merely on producing an item from discarded materials.

This article proposes a conceptual framework rather than reporting measured effects. Teachers are encouraged to adapt the sequence to local waste conditions, curriculum objectives, student readiness, and safety requirements. Further empirical studies should implement the framework in different school levels and examine changes in environmental literacy and scientific skills using valid instruments, comparison designs where feasible, and follow-up observations of students' waste-related practices.

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