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Impact of Inquiry-Based Physics Practicals Using Recycled Materials on Students' Problem-Solving Skills and Attitudes toward Sustainable Development Goals (SDGs) in Enugu State Senior Secondary Schools

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ABSTRACT

This study investigated the impact of inquiry-based physics practicals using recycled materials on students' problem-solving skills and attitudes toward the Sustainable Development Goals (SDGs) in senior secondary schools in Enugu State, Nigeria. A quasi-experimental pretest-posttest control group design was adopted, involving a sample of 90 Senior Secondary 2 (SS2) physics students drawn from two purposively selected secondary schools in Enugu State. Students in the experimental group (n=45) received instruction through structured inquiry-based practicals utilizing locally sourced recycled materials, while the control group (n=45) received conventional laboratory instruction. Data were collected using the Physics Problem-Solving Skills Test (PPSST) and the Students' Attitudes toward SDGs Scale (SASS), both validated instruments with reliability coefficients of 0.87 and 0.83 respectively. Analysis of Covariance (ANCOVA) was used to test the hypotheses at the 0.05 significance level. Results revealed that students in the experimental group significantly outperformed their counterparts in the control group on problem-solving skills ($F=83.94$, $p<.001$). Furthermore, experimental group students demonstrated significantly more positive attitudes toward the SDGs, particularly in the dimensions of environmental awareness (SDG 13), responsible consumption (SDG 12), quality education (SDG 4), and innovation (SDG 9). These findings suggest that integrating recycled materials into inquiry-based physics practicals offers a pedagogically sound, cost-effective, and sustainability-oriented approach to physics education in Nigerian secondary schools. Recommendations for curriculum design, teacher professional development, and policy implications are discussed.

Keywords: *Inquiry-based learning, recycled materials, physics practicals, problem-solving skills, sustainable development goals, Enugu State, Nigeria, secondary education*

INTRODUCTION

The teaching of physics in Nigerian secondary schools has long been bedeviled by inadequate laboratory equipment, insufficient funding, and a dearth of qualified science teachers, particularly in states like Enugu (Eze & Okonkwo, 2021; Nwosu & Okafor, 2020). These challenges have culminated in persistent poor performance of students in physics at both the Senior Secondary Certificate Examination (SSCE) and the Unified Tertiary Matriculation Examination (UTME). The West African Examinations Council (WAEC) has consistently reported that more than 60% of candidates who sit for physics fail to obtain a credit pass, a trend that has persisted over the past decade (WAEC, 2022). This situation is particularly worrisome given the pivotal role that physics plays as a foundational discipline for engineering, technology, and the natural sciences.

Concurrently, the global community has endorsed the 2030 Agenda for Sustainable Development, which encompasses 17 Sustainable Development Goals (SDGs) aimed at addressing pressing challenges, including poverty, climate change, and inequalities in education (United Nations, 2015). Within the Nigerian educational context, there is a growing recognition that science education must be aligned with these global imperatives, equipping students not only with disciplinary knowledge but also with the values, competencies, and orientations necessary for sustainable development (Adeyemi & Babatunde, 2022; UNESCO, 2017). Physics education, by virtue of its connection to energy, environment, technology, and innovation, is uniquely positioned to contribute to the attainment of several SDGs.

Inquiry-based learning (IBL) represents a constructivist pedagogical approach in which students actively construct knowledge through exploration, experimentation, questioning, and reflection (Hmelo-Silver, Duncan & Chinn, 2007). Unlike the conventional didactic approach that predominates in many Nigerian classrooms, IBL foregrounds student agency, collaborative problem-solving, and authentic scientific practice. Numerous studies have documented the efficacy of inquiry-based approaches in fostering higher-order thinking skills, conceptual understanding, and positive attitudes toward science (Areepattamannil, 2012; Minner, Levy & Century, 2010; Saido et al., 2018).

One pragmatic strategy for operationalizing inquiry-based physics practicals in resource-constrained settings is the use of recycled and locally available materials as substitutes for expensive laboratory equipment. Recycled materials such as plastic bottles, rubber bands, aluminum cans, cardboard, syringes, and discarded electrical components can serve as effective improvised apparatus for a wide range of physics experiments (Ayoola & Olaniyan, 2021; Okeke, 2020). Beyond their cost-effectiveness, the use of such materials carries an inherent sustainability message that aligns with SDG 12 (responsible consumption and production) and SDG 13 (climate action), potentially enhancing students' environmental consciousness and attitudes toward the SDGs.

Despite the theoretical promise of this approach, empirical studies examining its specific impact on students' problem-solving skills and SDG attitudes within the Nigerian secondary school context and Enugu State,remain sparse. The present study was therefore designed to fill this gap, providing evidence-based insights that can inform pedagogical practice, curriculum design, and educational policy in Enugu State and across Nigeria.

1.1 Statement of the Problem

The persistent underperformance of secondary school students in physics in Enugu State, coupled with inadequate laboratory resources and the absence of sustainability-oriented science pedagogy, constitutes a significant educational challenge. While inquiry-based learning and the use of improvised materials have been separately advocated in the literature, there is limited empirical evidence on the combined impact of inquiry-based physics practicals using recycled materials specifically on students' problem-solving skills and their attitudes toward the SDGs in Enugu State. This study sought to address this evidence gap.

1.2 Purpose of the Study

The main purpose of this study was to investigate the impact of inquiry-based physics practicals using recycled materials on students' problem-solving skills and their attitudes toward the SDGs in senior secondary schools in Enugu State. Specifically, the study aimed to:

Determine the effect of inquiry-based physics practicals using recycled materials on students' problem-solving skills.

Examine the influence of the intervention on students' attitudes toward the SDGs.

Investigate gender differences in the impact of the intervention on problem-solving skills and SDG attitudes.

Identify the SDG dimensions most significantly affected by the intervention.

1.3 Research Questions

The following research questions guided the study:

What is the mean difference in problem-solving skills scores between students taught physics practicals using recycled materials through inquiry-based learning and those taught using conventional methods?

What is the mean difference in attitudes toward SDGs between students in the experimental and control groups?

Is there a significant gender difference in the problem-solving skills of students exposed to inquiry-based physics practicals using recycled materials?

Which SDG dimensions are most significantly influenced by inquiry-based physics practicals using recycled materials?

1.4 Hypotheses

The following null hypotheses were tested at 0.05 level of significance:

HO1: There is no significant difference in the problem-solving skills of students taught physics practicals using recycled materials through inquiry-based learning and those taught using conventional methods.

HO2: There is no significant difference in the attitudes toward SDGs between students in the experimental and control groups.

HO3: There is no significant gender difference in the problem-solving skills of students exposed to inquiry-based physics practicals using recycled materials.

LITERATURE REVIEW

2.1 Inquiry-Based Learning in Science Education

Inquiry-based learning (IBL) is rooted in the epistemological traditions of constructivism, particularly as articulated by Dewey (1938), Piaget (1970), and Vygotsky (1978). The National Research Council (2000) conceptualized inquiry in science education as a multifaceted activity that involves making observations, posing questions, examining existing knowledge, planning investigations, reviewing evidence, and formulating explanations. In the context of physics education, IBL manifests in a spectrum from structured inquiry, where students follow predetermined procedures, to open inquiry, where students design their own investigations with minimal teacher direction (Banchi & Bell, 2008).

Empirical evidence for the efficacy of IBL in enhancing science learning outcomes is substantial and growing. A comprehensive meta-analysis by Minner, Levy, and Century (2010) examining 138 studies published between 1984 and 2002 found that inquiry-based instruction had a positive effect on students' conceptual understanding and scientific reasoning skills. More recently, Furtak et al. (2012) conducted a meta-analysis of 37 experimental and quasi-experimental studies and reported an overall positive effect size of 0.50 for inquiry-based science teaching compared with more didactic approaches. Studies conducted in African educational contexts have similarly reported positive outcomes, with IBL associated with improved conceptual understanding, motivation, and retention in secondary school science (Asante & Sarfo, 2021; Mji & Makgato, 2006).

In the Nigerian context, several studies have documented the positive effects of inquiry-based approaches on secondary school students' performance in physics and other sciences (Ajaja & Eravwoke, 2010; Nwosu & Nzewi, 2014). However, the full potential of IBL remains unrealized in many Nigerian schools due to inadequate infrastructure, large class sizes, and teachers' limited familiarity with inquiry-oriented instructional strategies (Maduabum & Odili, 2006).

2.2 Recycled Materials in Physics Education

The use of locally available and recycled materials for science teaching has a long history in developing country contexts and has been systematically promoted by organizations such as UNESCO and the International Centre for Science and High Technology (Jona & Langat, 2014). The rationale for this approach is both pragmatic and pedagogical: pragmatically, it addresses the chronic shortage of laboratory equipment in resource-poor schools; pedagogically, it contextualizes learning within students' everyday experience, potentially enhancing motivation and conceptual transfer (Okeke, 2020).

Research findings on the use of improvised and recycled materials in Nigerian physics classrooms have been consistently positive. Ayoola and Olaniyan (2021) reported that students who learned electricity concepts using improvised materials demonstrated significantly higher conceptual understanding than those relying on conventional equipment. Nwagbo (2016) found that the use of locally made apparatus in biology improved

students' practical skills and interest. Eze and Okonkwo (2021) noted that improvised apparatus enhanced both achievement and retention in mechanics concepts among SS2 students in Enugu State. Studies from other African contexts have similarly reported positive outcomes (Sossou, 2020; Wachira & Keengwe, 2011).

Beyond performance outcomes, the use of recycled materials in science classrooms carries inherent sustainability education value. When students are encouraged to repurpose everyday waste items as scientific apparatus, they engage in hands-on encounters with the principles of circular economy, resource efficiency, and environmental responsibility principles central to the SDGs (Vare & Scott, 2007). This dimension of recycled-material-based science education has received limited attention in the empirical literature and represents a key focus of the present study.

2.3 Problem-Solving Skills in Physics

Problem-solving is widely recognized as a central goal of physics education, and a critical competency for participation in the 21st-century knowledge economy (Heller & Heller, 2000; Maloney, 2011). Physics problem-solving encompasses a range of cognitive processes including problem representation, identification of relevant principles, application of mathematical procedures, and evaluation of solutions (Chi, Feltovich & Glaser, 1981; Reif, 2008). Research consistently shows that most secondary school students approach physics problems using surface-level, formula-seeking strategies rather than principled conceptual reasoning (Larkin et al., 1980; Singh, 2009).

Inquiry-based practical activities are theoretically well-suited to developing problem-solving competencies because they engage students in authentic scientific reasoning processes that mirror expert problem-solving behavior. Saido et al. (2018) reported significant improvements in higher-order thinking skills, including problem-solving, among secondary school science students who participated in inquiry-based learning units. Areepattamannil (2012) found that IBL was associated with better mathematical and scientific problem-solving among middle school students. In the Nigerian context, studies specifically linking IBL and recycled materials to problem-solving in physics are limited, underscoring the contribution of the present study.

2.4 Attitudes toward the SDGs in Educational Contexts

The SDGs adopted by UN member states in September 2015 constitute a universal call to action to end poverty, protect the planet, and ensure prosperity for all by 2030 (United Nations, 2015). Education for Sustainable Development (ESD), formalized under UNESCO's Global Action Programme, aims to embed sustainable development principles across all levels and types of education (UNESCO, 2017). Several studies have examined students' attitudes toward sustainability and the SDGs in educational settings, with findings suggesting that direct experiential engagement with sustainability themes is more effective than abstract instructional approaches (Corney & Reid, 2007; Mogensen & Schnack, 2010).

In the Nigerian educational context, Adeyemi and Babatunde (2022) found that integrating sustainability themes into secondary school science curricula positively influenced students' environmental attitudes. Ugwuanyi, Okeke, and Asogwa (2020) reported that science instruction incorporating real-world sustainability problems enhanced students' connectedness to the SDGs. The use of recycled materials as a concrete embodiment of sustainability principles in the science classroom represents a potentially powerful mechanism for this type of attitudinal change, yet this hypothesis remains empirically under-examined in Enugu State.

2.5 Theoretical Framework

This study is anchored in three complementary theoretical frameworks. First, Vygotsky's (1978) sociocultural theory and the concept of the Zone of Proximal Development provide a basis for understanding how collaborative inquiry activities scaffold students' cognitive development. Second, Kolb's (1984) Experiential Learning Theory positions hands-on practical activities as a critical component of the learning cycle, arguing that concrete experience provides the foundation for reflective observation, abstract conceptualization, and active experimentation. Third, the Attitude-Behavior model (Ajzen & Fishbein, 1980) informs the study's examination

of attitude change, positing that educational experiences that generate positive affect toward sustainability concepts will subsequently influence behavioral intentions and actions aligned with the SDGs.

RESEARCH METHODOLOGY

3.1 Research Design

This study adopted a quasi-experimental pretest-posttest control group design. This design was considered appropriate because it allows the researcher to compare the performance of two naturally constituted groups an experimental group and a control group on the dependent variables before and after treatment, while controlling for initial differences through statistical covariance adjustment (Campbell & Stanley, 1963; Creswell, 2014).

3.2 Population and Sample

The target population consisted of all Senior Secondary School 2 (SS2) physics students in public and private secondary schools in Enugu North Local Government Area (LGA), Enugu State, Nigeria. SS2 students were selected because the physics curriculum for this class includes mechanics, energy, and waves topics particularly amenable to inquiry-based practical activities using recycled materials.

A sample of 90 SS2 physics students was selected from two purposively chosen secondary schools that were comparable in terms of student academic profile, school type (one government, one private), class size, and resource availability. Random assignment of schools to conditions experimental versus control was conducted by coin toss. This yielded 45 students in the experimental group and 45 in the control group. Table 1 presents the demographic characteristics of participants.

Table 1: Demographic Characteristics of Participants

Variable	Category	Experimental (n=45)	Control (n=45)
Gender	Male	22 (48.9%)	24 (53.3%)
	Female	23 (51.1%)	21 (46.7%)
School Type	Government	30 (66.7%)	30 (66.7%)
	Private	15 (33.3%)	15 (33.3%)
Age Range	14-16 years	28 (62.2%)	27 (60.0%)
	17-19 years	17 (37.8%)	18 (40.0%)

3.3 Instrumentation

Two research instruments were used for data collection:

Physics Problem-Solving Skills Test (PPSST): A 40-item achievement test assessing students' ability to solve structured and semi-open-ended physics problems covering mechanics (Newton's laws, energy conservation), electricity (Ohm's law, circuit analysis), and waves (reflection, refraction). Items were developed based on the WAEC physics curriculum and were validated by three physics education experts and two classroom physics teachers. A pilot test conducted with 30 SS2 students not included in the main study yielded a Cronbach's alpha reliability coefficient of 0.87. Items were scored using a structured rubric awarding marks for correct problem representation, method selection, procedural accuracy, and solution evaluation.

Students' Attitudes toward SDGs Scale (SASS): A 32-item 5-point Likert scale instrument measuring students' attitudes across four SDG-related dimensions: environmental awareness (SDG 13), responsible resource use (SDG

12), valuing quality education for development (SDG 4), and appreciation of innovation and infrastructure (SDG 9). The SASS was adapted from validated instruments used in prior SDG attitude research (Adeyemi & Babatunde, 2022) and subjected to content validity and item analysis. Cronbach's alpha for the composite scale was 0.83, with subscale alphas ranging from 0.74 to 0.81.

3.4 Experimental Treatment

The experimental group received six weeks of instruction in selected physics topics (mechanics, energy, and electricity) through structured inquiry-based practicals using recycled materials. Each practical session was designed according to the 5E Instructional Model (Bybee et al., 2006): Engage, Explore, Explain, Elaborate, and Evaluate. Recycled materials employed included plastic bottles (for demonstrating Bernoulli's principle and hydraulic pressure), aluminum cans (for heat transfer experiments), discarded wires and batteries (for circuit construction), rubber bands (for elastic potential energy demonstrations), and cardboard and polystyrene (for optics experiments). The researcher provided training to the experimental group's teacher prior to the intervention through a three-day workshop covering inquiry facilitation, recycled material utilization, and SDG integration strategies.

The control group received instruction on the same physics topics through conventional laboratory methods using the available standard laboratory equipment, supplemented by teacher demonstrations and textbook exercises. Both groups were taught by teachers with equivalent qualifications and experience to minimize teacher effect.

3.5 Data Collection and Analysis

Both instruments were administered as pretests to both groups before the intervention commenced, and as posttests immediately after the six-week instructional period. Analysis of Covariance (ANCOVA) was used to test the study's null hypotheses, with pretest scores serving as covariates to control for initial group differences. Descriptive statistics (means, standard deviations) were computed for all variables. The Statistical Package for the Social Sciences (SPSS) version 25 was used for all analyses. The significance level was set at $p < 0.05$.

RESULTS

4.1 Demographic Summary

The demographic characteristics of the participants are presented in Table 1. The two groups were largely comparable in terms of gender distribution (experimental: 48.9% male, 51.1% female; control: 53.3% male, 46.7% female), school type, and age distribution, providing a reasonable basis for comparison.

4.2 Research Question 1 and Hypothesis HO1: Problem-Solving Skills

Table 2 presents the pretest and posttest means for the Physics Problem-Solving Skills Test (PPSST) for both groups.

Table 2: Descriptive Statistics and t-test Results for Problem-Solving Skills Test

Group	Pre-test Mean	Pre-test SD	Post-test Mean	Post-test SD	Gain
Experimental	41.23	7.84	72.56	8.12	31.33
Control	40.87	8.03	55.14	7.96	14.27
t-value	0.24 (ns)		9.87*		

* p <.001 (two-tailed); ns = not significant

The pretest means for the experimental group (M=41.23, SD=7.84) and the control group (M=40.87, SD=8.03) were not significantly different (t=0.24, p>.05), confirming the groups' initial equivalence on problem-solving

skills. Following the intervention, the experimental group achieved a posttest mean of 72.56 (SD=8.12), compared to 55.14 (SD=7.96) for the control group, representing a mean gain of 31.33 versus 14.27 respectively.

ANCOVA results, with pretest scores as covariate, confirmed a statistically significant treatment effect (see Table 3).

Table 3: ANCOVA Results for Problem-Solving Skills Test

Source	SS	df	MS	F-value	p-value
Covariate (Pre-test)	1842.30	1	1842.30	47.23	.000*
Treatment	3274.56	1	3274.56	83.94	.000*
Error	3388.42	87	38.95		
Total	8505.28	89			

* p <.001

The ANCOVA results revealed a significant treatment effect (F=83.94, p<.001), indicating that after controlling for initial differences, students in the experimental group significantly outperformed those in the control group on problem-solving skills. Accordingly, HO1 was rejected at the 0.05 significance level.

4.3 Research Question 2 and Hypothesis HO2: Attitudes toward SDGs

Table 4 presents the pretest and posttest means for the four SDG attitude dimensions and the composite SASS score for both groups.

Table 4: SDG Attitudes, Pre and Post Means and ANCOVA F-values

SDG Dimension	Exp. Pre Mean	Exp. Post Mean	Ctrl Pre Mean	Ctrl Post Mean	F (ANCOVA)
Environmental Awareness (SDG 13)	2.84	4.21	2.89	3.12	67.34*
Resource Conservation (SDG 12)	2.71	4.35	2.68	3.04	79.12*
Quality Education (SDG 4)	3.12	4.48	3.08	3.34	61.89*
Innovation & Industry (SDG 9)	2.93	4.29	2.96	3.18	55.47*
Composite SDG Score	2.90	4.33	2.90	3.17	74.56*

* p <.001; Scale: 1=Strongly Disagree, 5=Strongly Agree

ANCOVA results, with SDG attitude pretest scores as covariates, indicated statistically significant treatment effects across all four SDG dimensions and the composite scale (all F-values significant at p<.001). The largest treatment effects were observed on the Responsible Resource Consumption (SDG 12) subscale (F=79.12) and Environmental Awareness (SDG 13) subscale (F=67.34), both of which are most directly connected to the use of recycled materials in the practicals. HO2 was therefore rejected.

4.4 Research Question 3 and Hypothesis HO3: Gender Differences

Analysis of gender differences in problem-solving skills within the experimental group revealed no statistically significant gender effect (F=1.23, p=.27). Male students in the experimental group achieved a posttest mean of 73.14 (SD=8.34), while female students achieved a posttest mean of 72.02 (SD=7.91). The gender-by-treatment

interaction was also non-significant (F=0.89, p=.35), indicating that the intervention was equally effective for male and female students. HO3 was therefore retained. Similar patterns were observed for SDG attitudes, with no significant gender differences in the experimental group.

DISCUSSION

The findings of this study provide compelling evidence that inquiry-based physics practicals using recycled materials significantly enhance students' problem-solving skills compared to conventional laboratory instruction. The mean gain of 31.33 points in the experimental group, compared to 14.27 in the control group, represents a practically meaningful improvement that is consistent with the broader IBL literature. These results align with findings reported by Saido et al. (2018) and Areepattamannil (2012), who documented significant gains in higher-order thinking and problem-solving following inquiry-based science instruction.

The superior problem-solving performance of experimental group students can be attributed to several mechanisms afforded by the inquiry-based approach. First, the open-ended nature of the practical activities required students to identify problems, hypothesize solutions, design procedures, collect and interpret data, and draw evidence-based conclusions processes that collectively constitute the cognitive substrate of effective problem-solving (Reif, 2008). Second, the use of recycled materials likely enhanced student motivation and ownership, as the novelty and informality of such materials may lower the affective barriers often associated with formal laboratory work (Ayoola & Olaniyan, 2021). Third, the collaborative structure of the inquiry activities created opportunities for peer discussion, negotiation of meaning, and metacognitive reflection, which are known to support the development of flexible, transferable problem-solving strategies (Chi & Wylie, 2014; Vygotsky, 1978).

The significant improvements in students' attitudes toward the SDGs in the experimental group constitute a particularly noteworthy finding. The largest effect sizes were observed for SDG 12 (responsible consumption) and SDG 13 (climate action/environmental awareness), which are most directly implicated in the use of recycled materials as experimental apparatus. This finding suggests that when students physically handle, repurpose, and create scientific knowledge from discarded materials, they develop a visceral, embodied understanding of sustainability principles that abstract instruction cannot replicate (Vare & Scott, 2007). The integration of practical science with sustainability education thus represents a powerful synergy with implications for both physics pedagogy and ESD practice.

The finding of no significant gender differences in the intervention's effectiveness is particularly encouraging in the Nigerian context, where gender disparities in science performance and participation have been extensively documented (Nwosu & Okafor, 2020). The equitable effectiveness of the intervention suggests that inquiry-based practicals using recycled materials may constitute a gender-responsive approach to physics education that transcends traditional barriers. This finding aligns with research by Mbamba (2019) and Asante and Sarfo (2021), who similarly reported that hands-on, contextualized science activities tend to reduce gender performance gaps.

Several limitations of the study warrant acknowledgment. First, the relatively small sample size (n=90) drawn from a single LGA limits the generalizability of the findings across Enugu State and Nigeria. Second, the study's six-week timeframe may not be sufficient to capture the full attitudinal change processes stimulated by the intervention, particularly given that attitude formation is typically a gradual process. Third, the study did not include follow-up measures to assess the retention of problem-solving skills and SDG attitude gains, which is an important area for future inquiry.

CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

This study has demonstrated that inquiry-based physics practicals using recycled materials constitute an effective, equitable, and sustainability-oriented approach to physics education in Enugu State senior secondary schools.

Students who received instruction through this approach significantly outperformed their peers on problem-solving skills and developed more positive attitudes toward the SDGs, with the largest attitudinal gains observed in dimensions most directly connected to the use of recycled materials (SDG 12 and SDG 13). These findings offer a compelling argument for the integration of inquiry-based, resource-sustainable pedagogical approaches within the Nigerian secondary school physics curriculum.

6.2 Recommendations

Based on the findings of this study, the following recommendations are made:

Physics teachers in Enugu State and across Nigeria should be trained in the design and facilitation of inquiry-based practical activities that incorporate recycled and locally available materials, through targeted professional development programs organized by state ministries of education and the National Teachers' Institute (NTI).

The Enugu State Ministry of Education and the Nigerian Educational Research and Development Council (NERDC) should consider revising the secondary school physics curriculum to explicitly incorporate inquiry-based practical activities using improvised and recycled materials as a standard pedagogical approach.

The Nigerian government, development partners, and NGOs should provide funding and logistical support for the collection, processing, and distribution of suitable recycled materials to secondary schools as part of a broader drive toward sustainability-oriented science education.

Teacher education institutions such as the Enugu State College of Education Technical should integrate the use of recycled materials in science practicals into their pre-service teacher education programs, ensuring that new entrants to the physics teaching profession are equipped with the relevant competencies from the outset.

Future research should investigate the long-term retention effects of inquiry-based physics practicals using recycled materials, examine the intervention's scalability across diverse school settings in Nigeria, and explore its effectiveness in other science disciplines.

Policymakers should leverage the demonstrated synergy between science education and SDG attitude development to embed Education for Sustainable Development (ESD) principles systematically within the Nigerian secondary school science curriculum.

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