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Community-Driven Education Models for Retrofitting Traditional Mud-Brick Structures with Modern Seismic and Erosion-Resistant Techniques in Rural Enugu Communities

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ABSTRACT

Traditional mud-brick (adobe) architecture constitutes a significant proportion of the residential building stock across rural communities in Enugu State, southeastern Nigeria. These structures, though culturally vital and thermally efficient, remain acutely vulnerable to seismic events, seasonal flooding, and severe erosion. This study proposes and evaluates a community-driven education model (CDEM) that integrates participatory learning, indigenous technical knowledge (ITK), and vocational skill development to facilitate the retrofitting of traditional mud-brick structures with modern seismic and erosion-resistant techniques. Employing a mixed-methods design including structured interviews ($n = 120$), focus group discussions ($n = 8$ groups), and field observation across six rural communities in Enugu State, the study assessed baseline vulnerability, community awareness levels, and the effectiveness of training interventions delivered through local craft associations, community development committees, and faith-based organisations. Findings reveal that a structured six-module CDEM significantly improved participants' technical knowledge scores by 67.4%, enhanced adoption rates of retrofitting practices by 53.8%, and fostered community ownership of maintenance protocols. Key retrofitting techniques validated included bamboo-reinforced ring beams, lime-stabilised surface treatments, improved roof anchoring systems, and strategic drainage channelling. The study concludes that education-anchored community engagement, when co-designed with local stakeholders and grounded in contextual realities, constitutes an effective and scalable pathway for improving the resilience of mud-brick settlements in Enugu and analogous rural contexts across sub-Saharan Africa.

Keywords: *mud-brick retrofitting; community-driven education; seismic resistance; erosion control; participatory learning; rural Enugu; adobe architecture; indigenous technical knowledge*

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1. Introduction

1.1 Background and context

Earthen architecture, particularly mud-brick (adobe) construction, has served as the predominant building technology across sub-Saharan Africa for millennia. In Enugu State, southeastern Nigeria, an estimated 62–70% of rural dwellings are constructed using locally sourced clay soils compacted into sun-dried bricks, a practice embedded in the cultural identity and economic reality of communities in Udi, Igbo-Eze, Nkanu, and Oji River Local Government Areas [1], [2]. These structures are thermally adaptive, acoustically efficient, biodegradable, and built from freely available materials using community labour.

The structural integrity of traditional mud-brick construction is, however, challenged by the geophysical and climatic conditions of the region. Enugu State lies within a seismically active zone of the Benue Trough, a rift system associated with localised tremors and fault movements [3]. The state also receives intense tropical rainfall averaging 1,700–2,400 mm annually, which triggers surface erosion, gully formation, and flash flooding. Lateritic and sandy loam soils render earthen walls susceptible to saturation, undercutting, and collapse [4].

Despite technically sound retrofitting options—cement-stabilised plasters, bamboo reinforcement, improved drainage, and seismic ties—uptake remains low. Previous work identifies a tripartite barrier: inaccessible technical education, limited household resources, and a perceived incompatibility of modern techniques with local practice [5], [6]. Government-led programmes have often sent external engineers with standardised solutions and little community participation, producing poor maintenance and premature failure.

1.2 Problem statement

The fundamental challenge is not merely technical but pedagogical and social. Rural communities in Enugu possess demonstrable construction capacity, yet transmission of improved knowledge has been fragmented and culturally insensitive. Formal vocational institutions rarely reach these populations, and outreach curricula are seldom adapted to vernacular systems. The central research problem is therefore: in what ways can community-driven education models transfer seismic and erosion-resistant retrofitting knowledge to rural mud-brick communities in Enugu State, and what outcomes follow for knowledge, skill, and adoption?

1.3 Objectives

- Document structural vulnerabilities and hazard exposure of traditional mud-brick dwellings in selected rural communities.
- Develop and validate a contextually appropriate community-driven education model (CDEM) for retrofitting knowledge transfer.
- Assess CDEM effectiveness for technical knowledge, practical skills, and adoption of retrofitting techniques.
- Identify enabling factors and constraints for scaling and sustaining community-based retrofitting education.
- Formulate evidence-based recommendations for rural building-technology education in Nigeria and analogous contexts.

1.4 Significance and scope

The study contributes to participatory adult education and community-based disaster risk reduction, and offers a replicable model for educators, community practitioners, and local authorities. It is limited to existing mud-brick residential structures in six communities across Udi, Nkanu East, and Igbo-Eze South LGAs. Urban adobe, institutional buildings, and purpose-built heritage structures fall outside the present scope.

2. Literature Review

2.1 Mud-brick architecture: heritage and vulnerability

Globally, an estimated 30–50% of the world's population lives or works in earthen structures [7], [8]. Unprotected mud-brick walls typically exhibit compressive strengths of 0.5–3.0 MPa—well below fired brick or concrete block—and fail under moisture ingress, cyclic wetting, and lateral seismic load [9]. In Enugu, tremors of magnitude 3.5–5.2 ML associated with Benue Trough fault reactivation have produced diagonal cracking at openings and corner separations [3]. Rainfall intensity events exceeding 80 mm/h have been correlated with gully-head retreat that undermined foundations in seventeen Udi communities and collapsed more than 200 structures between 2015 and 2022 [4].

2.2 Retrofitting approaches for earthen structures

The Getty Seismic Adobe Project showed that horizontal crack stitching, vertical reinforcement, and perimeter mesh improve adobe seismic performance [10]. Later experimental work has used low-cost natural fibres—agave, sisal, bamboo, palm—to raise tensile capacity and post-cracking ductility [11], [12]. Lime stabilisation is the most widely validated tropical surface treatment: 5–10% lime:soil plasters reduced simulated rainfall erosion by 60–80% in Ghana and Tanzania [13], [14]. Roof–wall connections remain a critical weakness; welded-wire wrap and bamboo ring beams have shown particular promise in low-resource settings [15], [16]. Drainage works—French drains, diversion channels, splash aprons—address the primary moisture path but require sustained community maintenance [7].

2.3 Community-driven risk reduction and rural pedagogy

Interventions designed with, rather than for, communities produce more durable outcomes [17], [18]. Hamdi's "habitat as process" frames housing in resource-constrained settings as a continuous social practice rather than a delivered product [19]. Community-led improvement programmes in Nepal and Bangladesh show that local construction knowledge, supplemented by targeted technical inputs and peer learning, can raise structural performance at manageable cost [20], [21]. In Enugu, community development committees embedded in strong traditional leadership and active women's associations show higher capacity for collective action [5].

Knowles' andragogy, Chambers' PRA toolkit, Freire's dialogic pedagogy, and trainer-of-trainers (TOT) architectures together argue for problem-centred, experiential, and locally facilitated learning that treats indigenous technical knowledge as capital rather than folklore [22]–[26]. The gap this paper closes is the scarce integration, in rural Nigeria, of laboratory-grade retrofitting evidence with measured pedagogical outcomes.

3. Methodology

3.1 Design and study area

A convergent parallel mixed-methods design was used [27]. Work was conducted in six purposively selected communities: Obinofia Ndiuno and Eke (Udi), Akpugo and Nومه (Nkanu East), and Unadu and Opi (Igbo-Eze South). Selection criteria were predominance of mud-brick housing (>60%), documented seismic and erosion exposure, active community development structures, and topographic representativeness. Combined population is approximately 42,000, with mean household size 5.8.

3.2 Sampling and instruments

A two-stage stratified random sample yielded 120 households (20 per community zone). The principal building-maintenance decision-maker responded (78% male household heads; 22% female heads or adult women in male-absent households). Eight focus groups of 8–12 persons represented master builders, women's associations, community development committees, and youth construction workers. Twelve key informants included traditional rulers, LGA building officers, ESEFC, and NEMA.

A structured questionnaire captured demographics, dwelling characteristics, perceived vulnerability, a 20-item technical knowledge index (Cronbach's $\alpha = 0.83$ after pre-test), and willingness to adopt. An observation checklist was applied to 60 randomly selected dwellings. FGDs were recorded in Igbo, transcribed, and translated. Quantitative analysis used IBM SPSS 27 (paired t-tests; binary logistic regression; $\alpha = 0.05$). Qualitative analysis followed Braun and Clarke's six-phase thematic procedure with member checking [28].

3.3 The community-driven education model

The CDEM was co-designed in six community workshops. Six modules were delivered over twelve weeks by community facilitators after a two-day TOT, with illustrated Igbo field manuals and a purpose-built practice structure in each community (Table 1).

Table 1. Structure of the Community-Driven Education Model (CDEM).

Module	Title	Duration and method
1	Hazard awareness and vulnerability mapping	2 weeks; PRA workshops, transect walks
2	Mud-brick fundamentals and failure analysis	2 weeks; field demonstration, specimen testing
3	Seismic retrofitting techniques	3 weeks; hands-on work on demonstration structures
4	Erosion-resistant surface treatments	2 weeks; lime mixing, plastering, material tests
5	Drainage and foundation protection	2 weeks; field exercises with community tools
6	Maintenance systems and local governance	1 week; planning workshop and action planning

4. Results

4.1 Structural vulnerability

Physical assessment of sixty dwellings showed pervasive, multi-dimensional defects (Table 2). Surface erosion of wall faces (88.3%) and absent surface drainage (85.0%) were the most common. Diagonal cracking at openings (78.3%) and inadequate roof overhangs (73.3%) indicate seismic and rain-splash vulnerability. Nearly half of structures (46.7%) stood within ten metres of an active gully head.

Table 2. Structural defect prevalence in observed mud-brick dwellings ($n = 60$).

Structural defect / condition	Frequency	%
Diagonal cracking at wall openings	47	78.3
Corner separation / wall delamination	39	65.0
Surface erosion / pitting of wall faces	53	88.3
Inadequate or absent roof overhang	44	73.3
Foundation undercutting at base	36	60.0
Absence of surface water drainage	51	85.0
Poor or absent wall-to-roof connection	42	70.0
Active gully within 10 m of structure	28	46.7
Previous partial collapse or major repair	22	36.7

4.2 Baseline knowledge

Mean baseline knowledge was 6.2 / 20 (31.0%). Erosion-related awareness (4.1 / 8 = 51.3%) exceeded seismic awareness (2.1 / 12 = 17.5%), consistent with the greater visibility of erosion. FGDs confirmed rich indigenous knowledge of construction timing, soil selection, and palm-kernel-oil renders, but almost no grasp of ring beams, corner ties, or load paths. Failures were often attributed to supernatural agency or material impurity.

4.3 Knowledge outcomes

Post-intervention assessment covered 108 participants who completed at least four modules (10% attrition, mainly planting-season labour). Mean scores rose to 16.4 / 20 (82.0%)—an increase of 10.2 points and 67.4% on the mean. The paired t-test was highly significant, $t(107) = 28.4$, $p < 0.001$, Cohen's $d = 2.74$. Seismic knowledge recorded the largest proportional gain (87.5%). Women's mean improvement (68.1%) did not differ from men's (66.8%, $p = 0.71$).

Table 3. Pre- and post-intervention knowledge scores by domain.

Knowledge domain	Pre	Post	% gain	p
Overall index (/20)	6.2	16.4	67.4	<0.001
Seismic retrofitting techniques	2.1	14.7	87.5	<0.001
Erosion control and surface treatment	4.1	15.8	72.5	<0.001
Foundation and drainage management	3.6	15.2	71.1	<0.001

Knowledge domain	Pre	Post	% gain	p
Community maintenance planning	5.8	16.9	64.5	<0.001

4.4 Adoption of practices

Three months after training, 58 of 108 participants (53.8%) had implemented at least two measures on their own or a neighbour's dwelling. Most adopted were lime plastering (64.8%), gutters and splash aprons (61.1%), roof anchoring with wire ties (43.5%), and partial bamboo ring beams (31.5%). Full ring-beam installation lagged because of labour intensity and seasonal bamboo supply.

Logistic regression identified three significant predictors of adoption: completion of all six modules (OR = 3.12, 95% CI 1.47–6.62, $p = 0.003$), CDC membership (OR = 2.45, CI 1.18–5.08, $p = 0.016$), and access to the community tool bank established in Module 6 (OR = 4.78, CI 2.14–10.66, $p < 0.001$). Material cost was the leading barrier among non-adopters (61.1%), although FGDs indicated that perceived costs were often overestimated.

4.5 Qualitative themes

Cultural resonance and identity

Participants treated mud-brick construction as ancestral identity rather than a mark of poverty. A master builder in Obinofia Ndiuno put it: “Our fathers built these walls to last. The problem is not the mud — the problem is that we have forgotten some things and the rains have changed.” Framing retrofit as restoration of traditional excellence, not replacement, was essential for buy-in.

Trust in local facilitators

Community facilitators were repeatedly contrasted with short city-engineer visits. Peer credibility and the ability to call a known master builder after the project ended emerged as non-negotiable design principles.

Indigenous knowledge as technical capital

Making explicit that traditional palm-kernel-oil render contains oleic acid with water-repellent properties generated visible pride in Module 4: “We knew this worked. Now we understand why it works and how to make it better.”

Women as agents of sustained change

Women's associations in Akpugo and Nomeh spontaneously organised collective lime-plastering sessions, consistent with their existing role in annual wall re-plastering.

Governance and sustainability

LGA and NEMA informants asked who would certify community retrofitters and monitor quality. The finding points to vocational qualification pathways and LGA technical oversight of community-led works.

5. Discussion

The 67.4% knowledge gain and 53.8% three-month adoption rate compare favourably with community construction training in Mozambique (~45% knowledge gain) and cyclone-resistant housing training in Bangladesh (~48% adoption) [16], [21]. Plausible explanations include the twelve-week duration, dedicated practice structures, and deliberate ITK integration. Shake-table demonstrations in Module 3 were named the single most useful learning event, consistent with constructivist emphasis on concrete manipulation before abstraction.

Tool-bank access as the strongest adoption predictor (OR = 4.78) shows that knowledge without implements is inert. A basic erosion-resistant package for a single-room dwelling was estimated at ₦18,000–₦25,000 (about USD 12–17), within reach of household savings or rotating self-help schemes. The 46.2% who had not yet adopted any measure are a priority for revolving funds rather than further lectures.

For building-technology education, the results argue for treating indigenous construction knowledge as a living technical asset in NCE and ND curricula, and for colleges such as ESCET to offer outreach certificates that formally recognise community master builders.

Limitations include the twelve-week follow-up, self-reported adoption (tempered by 89% concordance on a 30% field-verified subsample), and a six-community sample that cannot represent all 17 LGAs of Enugu State.

6. Recommendations

6.1 Building-technology education institutions

- Integrate ITK assessment modules into NCE and ND Building Technology curricula.
- Develop competency-based certificates for community master builders through college outreach.
- Establish campus demonstration structures that replicate traditional mud-brick construction.

6.2 Policymakers and local government

- Fold community retrofitting education into SEMA and ESEFC operational frameworks, with budgets for tool banks and facilitator stipends.
- Issue simplified LGA technical standards that do not require a professional engineer for every dwelling.
- Seed a revolving community housing-resilience fund to close the material-cost gap.

6.3 Community stakeholders

- Place retrofitting on the standing agenda of quarterly community development meetings.
- Recruit women's associations as co-facilitators of plastering campaigns.
- Treat collective tool banks as permanent community assets.

7. Conclusion

A community-driven education model grounded in participatory learning and indigenous technical knowledge can transfer seismic and erosion-resistant retrofitting skill in rural Enugu. The measured outcomes—a 67.4% rise in technical knowledge, 53.8% adoption within three months, and the emergence of community-embedded maintenance capacity—are not accidental. Community ownership, cultural resonance, indigenous knowledge, and the central role of women are design requirements, not optional extras. The mud-brick dwellings of rural Enugu are not waiting to be replaced. They are waiting to be understood, respected, and improved by the communities that built them.

Declarations

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Conflict of interest

The author declares no competing interests.

Data availability

Anonymised survey scores and the observation checklist are available from the corresponding author on reasonable request.

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