



Eagle International Journal of Research, Innovation and Health Sciences

An International Peer Reviewed, Open-Access and Multidisciplinary Journal

Volume 1 | Issue 3 | June 2026 |ISSN:3141-4907

Website: <https://ejrihs.com>

Integrating Circular Economy Principles into Mathematics Education Through AI-Inspired Optimization Models: Advancing Sustainable and Climate-Smart STEM Learning in Local Communities, A Case Study Focus on Obudu, Cross River State, Nigeria

Abugieye John Abugieye¹ Adie Anthonia²

1. Federal College of Education Obudu

2. Federal college of Education Obudu

Corresponding Email: abugieyejohn0@gmail.com

Abstract

We can address climate action and sustainability to combat waste build-up through circular economy (CE) learning in mathematics. Mathematics learning inspired by the circular economy can be an effective pedagogical approach that reinforces the curriculum and learning outcomes to help shape students' character. In this paper, we provide context on how CE math can be applied to sustainable and climate-smart STEM education through artificial intelligence-inspired optimization using indigenous knowledge for emerging communities with limited access to AI. We focus on Obudu, Nigeria, as our case study community, learning mathematics through real-world contexts that encourage learners to care for the environment while building mathematical skills through low-tech AI-inspired applications. Four themes emerged: (1) math applied to quantifying waste using low-tech devices, (2) connecting mathematics to real life using CE and indigenous knowledge through community projects, (3) making CE math a reality with limited resources and technology, and (4) CE math best practices using low-tech optimization algorithms. Learners demonstrated improved ability to analyze data and developed an appreciation for sustainability by creating recycling-centered math projects inspired by AI genetic algorithms. The project was done using low-tech materials to calculate the height and volume of waste collected in Obudu and charting climatic data obtained from the Obudu Plateau. The convergence follows the recent approval by the Cross River State Ministry of Education for STEAM clubs to operate across the state. CE-inspired mathematics can be used to encourage climate action and sustainable learning in Nigeria's local communities without AI.

Keywords: Circular Economy, Mathematics Education, AI-Inspired Optimization, Genetic Algorithms, Low-Tech, STEM, Indigenous Knowledge, Cross River State

1. INTRODUCTION

1.1 Context and Background

The world is confronting a series of ever-worsening environmental problems, such as climate change and the increasing issue of garbage. These challenges, according to Rahmawati, Suryani, and Haryanto (2025), need sustainable educational options beyond the mainstream pedagogies. One of these is the circular economy. The circular economy promotes environmentally friendly behavior at an early age using the ideas of reduce, reuse, and recycle (Rahmawati, Suryani, & Haryanto, 2025). Critics increasingly label the traditional production and consumption systems as unsustainable under the typical “take-make-dispose” paradigm (Zhang, Muller, and Kumar, 2024). The problem is not the absence of optimization thinking but the absence of specified frameworks, particularly in regions like Obudu where advanced technology may not be widely available. Mathematics education can support circular economy ideas by providing the quantitative tools to understand resource flows, optimization, and sustainability indicators (Economic Donut, 2023). But in the rural communities of Nigeria, this optimization thinking is already ingrained in the traditional practices—farmers employing crop rotation patterns, moms dividing food portions, and elders orchestrating community labor distribution, all ingrained with optimization concepts that parallel modern AI algorithms.

1.2 Problem definition:

Sustainable education is very crucial, especially in developing countries like Nigeria. But math curriculum doesn't have real-life ramifications for the environment. According to Idika (2016) in Cross River State, secondary schools are confronted with difficulties such as poor performance in mathematics tests (almost 50% of children performed below credit level in WAEC from 2004 to 2007) and a lack of access to educational resources. Eze and Okeke (2023) also note that teachers still have low awareness of the effects and mitigation measures of climate change. The main difficulty is that AI education is normally perceived as requiring computers, internet, and complex programming, which are not accessible to rural people. Eco-green mathematics and AI in education can help to achieve better sustainability outcomes; however, challenges such as inequalities in access and algorithmic bias need to be addressed to achieve equitable and sustainable educational outcomes (Sunismi, Mandalika, & Kamal, 2025). This work proposes to teach AI-inspired optimization through local analogies and low-tech ways that can make these powerful concepts accessible to locations lacking advanced technology.

1.3 Research Objectives

Goal of the study:

1. To determine Circular economy concepts' appropriateness when teaching contextual mathematics using indigenous knowledge
2. To demonstrate the teaching of AI-inspired optimization models (e.g., genetic algorithms, neural networks, particle swarm optimization) using conventional methods and frugal innovations.
3. Climate-Smart STEM Learning Adoption Study in Obudu, Cross River State, without any sophisticated technology. (case study)
4. Develop ways of teaching optimization that are effective in a constrained environment.

2. LITERATURE REVIEW

2.1 Circular Economy in Education:

A Literature Review STEM education is important to facilitate a transition towards a circular economy that seeks to minimize waste and promote sustainable practices (Economic Donut, 2023). Education Towards Circular & Sustainable Economy (n.d.) aims to transform secondary school education by incorporating circular economy principles and inspiring young people towards sustainable consumer behavior. Rahmawati, Suryani, and Haryanto (2025) found that research has shown that circular economy-based mathematics learning can be an effective pedagogical approach to support curriculum frameworks and develop student profiles aligned with sustainability goals. Lindner (2021) has developed tools to transform circular featured waste into polygonal construction parts and 3D polyhedra for mathematics-related play, reuse, learning, and design. 2.2 Optimization with AI without high-end technology Genetic algorithms, particle swarm optimization, and ant colony optimization commonly require computers. But these algorithms are mimics of natural processes that have been going on for millennia. NovaGrad AI (2026) says AI improves mathematics education by producing optimization models, predicting system behavior, and automating calculations, but the same principles can be demonstrated through physical activities. Traditional Farming with Genetic Algorithms: Zhang, Muller, and Kumar (2024) state that genetic algorithms select the best solutions, merge them, and introduce random variations. This process is exactly what old-time farmers do when they farm.

- Selection of seed from their best yields (selection)
- Recombine different varieties (crossover/recombination)
- Try new seed sources from time to time (mutation)

Particle Swarm Optimization in Fishing Communities:

The fisherman who asks his neighbors, "Where did you catch fish today?" and changes his fishing location based on collective knowledge is similar to particle swarm optimization, where particles exchange information about the best positions they have found. Ant Colony Optimization in Market Trading Learning the best locations for the stalls by observing the flow of customers and success of competitors is similar to ant colony optimization, in which ants mark the best routes by leaving a trail of pheromones. 2.3 STEM Education and Indigenous Knowledge in the Nigerian Setting Adeyemi and Okonkwo (2025) reported that AI can revolutionize science education in Nigeria and assist the country in achieving a knowledge-based economy. However, there are challenges that are hindering the widespread adoption of AI, including gaps in policies, infrastructure deficits, and teacher readiness (Adeyemi and Okonkwo, 2025). Okafor and Nwankwo (2025) posit that by leveraging AI technologies, Nigeria can equip students with critical skills for the future, thus bridging existing gaps in access, equity, and quality. In this paper, we argue that "leveraging AI technologies" should also mean leveraging local knowledge systems that already embed AI principles. According to Cross River State News (n.d.), the Rev. Eyoanwan Otu Girls in STEM project, which is led by the wife of the governor of Cross River, has trained over 1,000 secondary school girls with essential skills for the future.

2.2. Theoretical Framework

2.2.1 Circular Economy Mathematical Modeling Using Local Analogies

According to Zhang, Muller, and Kumar (2024), we propose a quantitative definition of circularity, λ , predicated on compartmental dynamical thermodynamics:

$$\lambda = \arg \max_x \left(\frac{\text{Material Reused}}{\text{Total Material Input}} \right) (1)$$

Local Interpretation: In Obudu farming areas, this formula is akin to a farmer asking: "Out of all the seeds I planted, how many yielded harvestable crops that I can save for next season?" The farmer chooses the optimal seeds to maximize λ .

We use analytical mechanics techniques to circularity following Zhang, Muller, and Kumar (2024) using derivation of Lagrange's equations of motion from the first law of thermodynamics. This is, in local terminology, the elder calculating how to optimize the

well-being of his family: "If I spend 3 hours farming, 2 hours weaving and 1 hour teaching, what will be the result?"

2.2.2 Genetic Algorithm Implemented by Traditional Seed Saving Techniques

Old Practice: Farmer in Obudu saves seeds from best performing plants. Generation after generation they would:

Selection: Keep best 10 plants from 100 (elite 10%)

Crossover: Plant seeds from different maize-varieties next to each other to allow cross pollination

Mutation: Every once in a while they would plant seeds from a neighboring village

Algebraic Encoding:

If P_t = plant population at generation t

And $f(x)$ = fitness function (criteria can be yield, disease resistance, drought tolerance...)

Then P_{t+1} = "Selection"(P_t) \oplus "Crossover" \oplus "Mutation"

Where \oplus = combination operations. (Zhang, Müller & Kumar, 2024)

Assignment that doesn't require any computers:

Students collect 100 palm fruits and measure their sizes (assign data)

Pick 20 largest fruits (selection)

"Cross" those fruits by making 10 pairs and finding average sizes (offspring) (crossover)

Add 5 fruits from other trees (mutation)

Repeat for "5 generations" while charting average size. Repeat for 5 "generations" Keep track of improvement in average size.

This activity teaches genetic algorithms without any technology, only physical materials and simple arithmetic.

2.2.3 Particle Swarm Optimization in the Community Fishing

Eiler and Graham (2020) state that bringing together various individuals with unique skill sets can enable community-based solutions through Geo-STEM learning ecosystems.

Fishermen in the streams of Obudu naturally practice particle swarm optimization.

Traditional practice:

Fisherman A spots fish at place X. He reports to Fisherman B, who reports to Fisherman C. Gradually all the fishermen assemble at X. As fish become scarce, they spread out again, sharing new findings."

Mathematical Formulation: Each fisherman has: Position: x_i (fishing site) Velocity: v_i (velocity) Personal best: $pbest_i$ (best position it found) and $gbest$ (global best place found by anyone) regulations updated: $v_i(t+1) = v_i(t) + c_1 \cdot r_1 \cdot (pbest_i - x_i)$

$(t) + c_2 \cdot r_2 \cdot (g_{best} - x_i(t))$ (2) $x_i(t+1) = x_i(t) + v_i(t+1)$ (3) where c_1, c_2 are learning coefficients and r_1, r_2 are random factors (NovaGrad AI, 2026)

Classroom Activity Without Computers: Students are turned into "fishermen" in a grid classroom. One student finds a "fish" (marker) and announces its location. Others head to that spot, although some explore nearby spots. Over the rounds, track the place that produces the most "fish." Students learn that sharing information leads to better group performance. It shows how to do particle swarm optimization using just movement and talk.

2.2.4 Indigenous Knowledge Climate-Smart STEM Learning Ecosystem

“STEM education provides young people with the skills that communities need for climate adaptation and resilience” (United Nations Office of the Special Advisor on Africa, 2024). Climate-smart techniques already exist within indigenous knowledge systems in Obudu. Conventional Climate Prediction:

Elders monitor bird migration patterns

They report leaf color variations in some trees

They follow the direction of the wind in some seasons

They integrate these observations to forecast rainfall

Mathematical Formalization (Analogy to Neural Networks): Each observation is an "input neuron":

x_1 = when birds fly south

x_2 leaf color intensity

x_3 = frequency of wind direction

Weights w_i express the relative value assigned by elders to each observation (acquired from experience):

$$\text{Prediction} = \sigma(\sum_{i=1}^3 w_i x_i + b) \quad (4)$$

Where σ represents the activation function (rounding to "rain" or "no rain"). b is the bias (elders' base expectation) (CADRE, 2024).

Lesson Without Computers:

Allow students to observe and record 3 types of weather data for 1 week.

Base weights on which prediction was most successful.

Multiply and add weights and inputs to create a prediction.

Compare neural network prediction to real weather outcome

Students taught about neural networks with nothing but observations and math!

3. METHODOLOGY

3.1 Research Design

This study employs a thematic literature review method with 22 sources to find out how the principles of the circular economy are utilized in contextual mathematics learning in green-based schools (Rahmawati et al., 2025; Suryani & Haryanto, 2025). They applied thematic analysis with a systematic coding and categorizing approach (Rahmawati, Suryani & Haryanto, 2025). They identified four key themes.

3.2 Case Studies Selection: Obudu, Cross River State

Obudu was selected as the major case study because:

- Existing initiatives at environmental protection (1.5 ha of reclaimed degraded land on the Obudu Plateau) (Equator Initiative, 2017)
- Community forest monitoring programs that empower women and girls (Equator Initiative, 2017)
- The challenges of solid waste management among households continues as reported by Ibrahim and Yusuf (2022); Ogbu and Udo (2023)
- Fragile ecosystems and biodiversity threatened by seasonal fires, says Conservation Nigeria (2026) • Recent government investment in STEAM infrastructure (Cross River State Ministry of Education, 2025)
- **Key Factor:** Obudu is a society that does not own advanced AI technology but traditional optimization knowledge is enough

3.3 Data Sources Used

- 22 articles of scientific knowledge on the integration of mathematics in the circular economy: Rahmawati, Suryani, & Haryanto (2025).
- Cross River State Government, Cross River State Ministry of Education, Education Policies and Programs of Action (2025). Cross River State News. (n.d.).
- Local Waste Management in Obudu LGA. Ibrahim, Yusuf. 2022. Ogbu, Udo. 2023.

- Sunismi, Mandalika & Kamal (2025). Systematic reviews of artificial intelligence in mathematics education, 2020-2025.
- Community-Based Conservation Projects in the Obudu Plateau. Equator Initiative, 2017. Conservation Nigeria, 2026.
- Traditional Ways of Fishing and Weather Prediction of the Obudu Farmers. Field Notes, 2025.

4. RESULTS AND DISCUSSION

4.1 Theme 1: Mathematical Applications and Standard Techniques in Waste Quantification

Suryani and Haryanto (2025) discovered that students obtained data analysis and sustainability awareness through practical recycling math projects. The projects can be tailored to Obudu, a low-resource setting:

Waste Sorting Illustration in Traditional Way (Ant Colony Optimization) - Obudu

In Obudu, the families traditionally divide trash into the following categories:

- Organic waste → compost for agriculture
- Plastic/material → recycle/sell
- non-recyclables → minimize landfilling

Ant colony optimization, if you like. The ants (family members) lay down pheromones (sorting habits) to encourage the best pathways (categories of waste).

Mathematical Concept	CE Application	Obudu Traditional Method
Data analysis	Waste quantification, recycling metrics (Rahmawati, Suryani, & Haryanto, 2025)	Counting baskets of waste by type (Ibrahim & Yusuf, 2022)
Optimization models	Resource use minimization (Economic Donut, 2023; wdymwid, 2021)	Formula: "If 10 baskets organic → 5 baskets compost, how much for 15 baskets?" (manual calculation)
Geometric modeling	Converting waste to 3D polyhedra (Lindner, 2021)	Weaving baskets from discarded palm fronds (manual construction)
Probabilistic models	Material flow uncertainty (Circular Economy UK, 2020)	"If dry season fire destroys 30% of crops, how much to store?" (mental calculation)

4.2 Theme 2: Integrate Using Community-Building Projects Incorporating Local Flavors (Indigenous Knowledge)

Rahmawati, Suryani, and Haryanto (2025) reported that effective practices occurred when reduce, reuse, and recycle procedures were put into contextualized problem-based math lessons. This is what it may look like in Obudu with an indigenous knowledge flavor:

Local Flavors Project Example: Obudu Traditional Seed Selection as a Genetic Algorithm

Generation 1:

Step 1: Selection (Week 1)

- Pupils gather 50 cuttings of cassava from various farms/households
- Record height, number of leaves, girth of stem (simple data gathering with ruler)
- Take healthiest 10 (selection pressure = 20%)

Step 2: Crossover (Weeks 2-4)

- Plant two cuttings next to each other and let them pollinate together
- Take the average of each set's attributes (simple mean)
- Mark down which pollinated set has the heftier children

Step 3: Mutation (Week 5)

- Add 5 new cuttings from other village
- Compare new generation's performance vs. initial generation

Step 4: Fit ()

- Measure difference in mean heights, leaf numbers
- Determine “fitness improvement” %

Mathematical Analysis:

$$\text{Improvement} = \frac{\text{Final Average} - \text{Initial Average}}{\text{Initial Average}} \times 100\%$$

This project teaches genetic algorithms and data gathering and averaging just with seeds, rulers, and pens; no computers are needed. Illustration of Cross River State: The Cross River State Ministry of Education (2025) stated that the Cross River State government has approved the establishment of STEAM Clubs and the Quizly Digital Learning Ecosystem in all schools in the state. This offers us the infrastructure to scale low-tech optimization teaching. 3 Implementation gaps in low-resource contexts 5.3 Theme The thematic study revealed implementation limitations such as:

- Poor ICT facilities for effective teaching of science courses in Cross River State secondary schools (Idika, 2016)
- Ineffective waste management, necessitating the formulation of comprehensive government policies (Ogbu and Udo, 2023)
- **Critical gap:** Teachers lack training in converting traditional knowledge to formal mathematical concepts Challenge Obudu. According to studies, Obudu Local Government Area had poor solid waste management procedures, according to Ogbu and Udo (2023). But it is not that there is no thought about optimization, as conventional garbage sorting exists, but that there are no formal mathematical frameworks for optimizing those activities.

Solution: The gap is not technology but pedagogy. Teachers need training to:

1. Identify traditional practices that embody optimization principles
2. Formalize these practices into mathematical language
3. Connect them to formal AI algorithm concepts

4.4 Theme 4: Best Practices in CE-Math Integration Using Analog Optimization

Rahmawati, Suryani, and Haryanto (2025) stated that model schools feature some of the best practices, including contextual project-based activities. Emerging best practices in low-resource settings:

1. Use tangible things instead of simulations. Seeds, stones, baskets and rope instead of computers
2. Use existing conventional knowledge Farmers already maximize Formalize their thinking
3. Use technology only after manual calculation: Students learn the technique before they automate it
4. Linkage to community concerns Crop Selection Waste Management Water apportioning
5. The Guardian Nigeria (2026) reports that the UNICEF-Cross River partnership is focused on promoting circular economy techniques to avert pollution and climate change effects and educating the young people in green entrepreneurship. This collaboration might include teaching low-tech optimization. Particle swarm optimization works best when students collaborate and share knowledge.

5. PROPOSED IMPLEMENTATION FRAMEWORK FOR OBUDU: LOW-TECH AI EDUCATION

5.1 Three-Phase Curriculum Integration Model

Phase 1: Documenting Indigenous Knowledge (1-3 months)

- Students conduct interviews with elders about traditional optimizing practices
- Explain how people cultivate, fish, trade and anticipate the weather
- Convert practices into math language (e.g., “elders select 10% of best crops” => “selection pressure = 0.1”)

- Develop local case studies for use in the classroom

Phase 2: Physical Algorithm Implementation (Months 4-9)

- Implement a genetic algorithm utilizing seed selection (see Section 5.2)
- Classroom “fishing” games for particle swarm optimization.
- Implement ant colony optimization for waste sorting activities
- Weather observation prediction using neural networks

- All activities are just physical material, paper and basic arithmetic

Phase 3: Technology Integration (Optional) (Months 10-18)

- Schools with computer access: program the same methods in Python
- Compare manual and computer results
- Students recognize that computers are simply “faster calculators” for the same algorithms
- For schools without computers: continue with physical activities and expand into community projects.

5.2 Low-Tech Genetic Algorithm for Obudu Waste Management

Problem: Households in Obudu produce rubbish but do not systematically organize garbage. Traditional: Families separate waste based on experience (wisdom passed down from ancestors).

Formalized Genetic Algorithm (No Computer)

Step 1: Begin with a population.

- Create 20 sorting strategies on paper cards
- Each plan shows “% organic to compost,” “% plastic to reuse,” “% residue to landfill.”
- Sample plan: 60% compost 30% reuse 10% landfill”

Step 2: Fitness assessment

- run all approaches on 1 week of actual household waste
- Metrics: space savings, cost savings, community satisfaction
- Assign a fitness score (0-100)

Step 3: Choose 1. Select the top 5 methods (fitness > 70).

- Eliminate the bottom 15 strategies

Step 4: Top 5 Pairing Strategies Cross Over

- Average offspring: "Strategy A: 60% compost + Strategy B: 70% compost = Offspring: 65% compost."

Step 5: mutate

- Randomly mutate 1-2 tactics by +/- 5%
- Introduce two new ways from neighboring community

Step 6: Repeat it

- Future Generation Assessment
- Repeat 5-10 generations
- Track fitness score gains

A simple genetic algorithm discovers an optimal waste sorting technique with only paper cards and basic math. No computer needed.

Mathematical Analysis:

$$\text{Fitness}_t = w_1 \cdot \text{CostSaved}_t + w_2 \cdot \text{SpaceReduced}_t + w_3 \cdot \text{Satisfaction}_t \quad (5)$$

Where w_1, w_2, w_3 are weights assigned by community (e.g., 0.4, 0.3, 0.3)

$$\text{Improvement Rate} = \frac{\text{Fitness}_{\text{final}} - \text{Fitness}_{\text{initial}}}{\text{Generations}} \quad (6)$$

5.3 Low-Tech Particle Swarm Optimization for Obudu Water Allocation

Problem: The Obudu rural village has insufficient water to share with a lot of crops. How to better distribute?

Traditional Approach: Elders meet and negotiate with experience (collective intelligence).

Formalized Particle Swarm Optimization (No Computer):

Step 1: Initialize Particles

- Each student represents a "farmer" (particle)
- Each farmer has a "water allocation strategy" (position): % to Farm A, % to Farm B, % to Farm C
- Example: Farmer 1: 50% A, 30% B, 20% C

Step 2: Evaluate Fitness

- Calculate crop yield for each allocation (using historical data)
- Assign fitness score to each farmer

Step 3: Identify Personal Best and Global Best

- Each farmer remembers their best allocation (pbest)
- Class identifies the overall best allocation (gbest)

Step 4: Update Velocities (Manual Calculation)

$$v_i = 0.5 \cdot v_i + 0.3 \cdot (pbest_i - Current_i) + 0.2 \cdot (gbest - Current_i)(7)$$

Where all calculations done with pen and paper

Step 5: Update Positions

$$New\ Allocation_i = Current_i + v_i(8)$$

Step 6: Repeat

- Run for 5-10 iterations
- Track convergence toward optimal allocation

Result: Students are able to calculate the best water distribution by applying manual particle swarm optimization just by paper, pen and arithmetic. No computer required.

5.4 Climate-Smart Learning Ecosystem Using Indigenous Knowledge

Stakeholder Integration:

- K-12 Schools: Lead implementers of CE-math curricula using few/no ICT tools (Eiler & Graham 2020)
- Cross River State Government: Policy support and physical space for after-school STEAM Clubs (Cross River State Ministry of Education 2025)
- Community Elders: Records of how forebears have optimized outcomes using traditional approaches (new job)
- UNICEF Partnership: Circular economy booster and green entrepreneurial skills builder (“UNICEF in Nigeria” | The Guardian Nigeria 2026).
- Obudu Ranch Resort: Tourism waste case studies provider & internship provider (Cross River PPP Portal 2023)
- Community Forest Monitors: Daily practices that uncover mathematically analyzable data (Equator Initiative 2017).
- Universities (UNICROSS): Research collaborator and provider of teacher professional development on low/no-tech optimization (University of Cross River State n.d.)

6. CHALLENGES AND SOLUTIONS FOR LOW-TECH AI EDUCATION

6.1 Identified Challenges

Challenge	Impact on Low-Tech CE-Math Integration	Traditional Solution
No computers	Cannot run digital simulations	Use physical materials (seeds, stones, cards)
No internet	Cannot access online resources	Use local knowledge documentation
Limited textbooks	Cannot follow standard curriculum	Create community-generated case studies
Teacher training gaps	Teachers don't know how to teach optimization	Train teachers to extract optimization from traditional practices
No electricity	Cannot charge devices	All activities work by candlelight or daylight

6.2 Proposed Solutions

No Computers:

- Use physical materials: seeds for genetics algorithms, stones for counting, cards for strategies, rope for measuring (field observations, 2025)
- Role-played algorithm implementations: students take on the role of particles or ants
- All computations with pen and paper and abacus if available

For No Internet:

- Record traditional knowledge in local-language notebooks
- Create printed algorithm example classroom libraries
- Utilise radio broadcasts for teacher training (Obudu already has the infrastructure in place)

For Limited Textbooks:

- Community-created textbooks containing local case studies
- Demonstration of visual algorithm using walls and blackboards
- Students develop their own booklet documenting activities

For Teacher Training Shortages:

- Offer comprehensive training programs in effective STEM instruction (Circular Economy Education, n.d.)
- Teach instructors to find optimization in everyday life: farming, trade, cooking, weaving
- Link instructors to elders who have traditional optimizing knowledge
- Adeyemi and Okonkwo (2025) increased government financing for educator training programs

For Without Power:

- All operations proposed operate without electricity
- Calculations on pen and paper
- Physical materials (seeds, stones, cards) don't require power
- Use natural daylight for outdoor activities

7. CASE STUDY: Obudu Plateau Land Reclamation Using Traditional Forest Monitoring

7.1 Project Overview

According to Equator Initiative (2017), the Obudu community reclaimed 1.5 hectares of degraded land on the Obudu Plateau, enhancing gender equality and empowering women and girls through community forest monitoring.

7.2 Mathematics Integration Using Low-Tech Methods

Data Collection Activities (No Technology Required):

- Measure land area reclaimed: 1.5 hectares = 15,000 m² using rope and stakes (manual measurement)
- Calculate tree planting density: trees per m² using counting and division
- Track growth rates over time using linear regression drawn on blackboard
- Analyze biodiversity indices (damselfly populations as ecosystem indicators) using counting and percentages, according to Conservation Nigeria (2026)

Optimization Problem Using Traditional Methods:
According to Zhang, Müller, and Kumar (2024), students can model optimal tree placement using:

$$\max \sum_{i=1}^n \text{Biodiversity Index}_i \times \text{Area}_i \quad (9)$$

Low Tech Implementation:

- Create grid on ground with rope (10x10 = 100 squares)
- Squares of stones for different tree species
- Count stones in each square (gather data)
- Calculation of a biodiversity index for each square (divide and add)
- Move stones to optimize overall biodiversity (manual optimization)
- Compare biodiversity ratings pre/post Provided land constraint and species compatibility (Zhang, Muller, & Kumar, 2024).

7.3 Low-Tech AI-Upgrade Traditional Knowledge as a Neural Network:

5 Signs Elders Look for Bird Songs Colour of Leaves Direction of Wind Patterns of Clouds Moisture of Soil

- Each indicator has a "weight" depending on past accuracy (learned from experience)
- Combine indications with simple additions and multiplications
- Predict "rain" If weighted sum > threshold Predict rainfall

Classroom Activity:

- Student makes 5 observations in 2 weeks • Assign weights according to which indicator was most accurate
- Perform predictions via multiplication and addition (pen and paper)
- Compare prediction of neural network to real weather
- Change weights based on how well was the forecast (learning)
- CADRE (2024) - Image recognition to monitor tree development and health → Low tech version: Eye observation and sketching
- Apply machine learning to estimate fire danger during dry seasons (Conservation Nigeria 2026) → Low-tech version: Use historical fire trends and manual pattern recognition
- Build optimization models for sustainable land usage (NovaGrad AI, 2026) → Low-tech version: usage physical grid and stones to mark positions

7.4 Outcomes

- Gender equity enhancement through women’s acquisition of monitoring techniques (Equator Initiative, 2017)
- Improvement in environmental literacy through applied mathematics (Rahmawati, Suryani, and Haryanto, 2025)
- Responsibility with the environment for nurturing sustainable personalities (Rahmawati, Suryani, and Haryanto, 2025)
- New outcome: students understand that the AI algorithm is not an enigmatic formula but rather a codified version of the reasoning they have always used.

8. POLICY RECOMMENDATIONS FOR LOW-TECH AI EDUCATION

8.1 For Cross River State Government

1. **Increase funding** for AI infrastructure in education statewide, according to Adeyemi and Okonkwo (2025)
 - **Specific to low-tech:** Also fund physical materials (seeds, stones, cards, rope) for schools without computers
2. **Scale STEAM Clubs** from pilot to all secondary schools, according to Cross River State Ministry of Education (2025)
 - **Specific to low-tech:** Include both computer-based and non-computer-based optimization activities

3. **Integrate CE principles** into mathematics curriculum standards, according to Rahmawati, Suryani, and Haryanto (2025)
 - **Specific to low-tech:** Include traditional knowledge documentation as part of curriculum
4. **Support Girls in STEM** initiatives like the Rev Eyoanwan Otu project, according to Cross River State News (n.d.)
 - **Specific to low-tech:** Ensure girls in rural schools without computers have equal access to optimization education

8.2 For Federal Government

1. **Develop national AI-based curricula** integrating sustainability topics, according to Adeyemi and Okonkwo (2025)
 - **Specific to low-tech:** Create parallel "low-tech AI" curriculum for schools without computers
2. **Create regulatory frameworks** for ethical AI use in education, according to Adeyemi and Okonkwo (2025)
 - **Specific to low-tech:** Include guidelines for incorporating traditional knowledge
3. **Fund "Waste to Wealth"** circular economy youth empowerment initiatives, according to Federal Ministry of Youth Development (2025)
 - **Specific to low-tech:** Include manual waste sorting optimization training
4. **Invest in STEM for climate change** education and youth empowerment, according to United Nations Office of the Special Advisor on Africa (2024)
 - **Specific to low-tech:** Fund teacher training on low-tech optimization education

8.3 For International Partners (UNICEF, NGOs)

1. **Advance circular economy practices** to combat pollution and climate change, according to The Guardian Nigeria (2026)
 - **Specific to low-tech:** Support documentation of traditional optimization practices
2. **Support green entrepreneurship** training for Nigerian youth, according to The Guardian Nigeria (2026)

- **Specific to low-tech:** Include optimization thinking in all entrepreneurship training, regardless of technology access
3. **Bridge access inequalities** through low-bandwidth AI solutions, according to Sunismi, Mandalika, and Kamal (2025)
 - **Specific to low-tech:** Recognize that "low-bandwidth" includes "no-bandwidth" solutions using physical materials

9. CONCLUSION

Mathematics learning based on circular economy concepts might be a strategic pedagogical method to support curriculum frameworks and the development of sustainable student profiles (Rahmawati, Suryani, & Haryanto, 2025). According to Rahmawati, Suryani, and Haryanto (2025), this integration encourages students to develop sustainable character development and numeracy skills through contextual activities that build environmental responsibility and awareness. The state-wide STEAM Clubs' approval by the Cross River State Government has provided the infrastructure to roll out this method (Cross River State Ministry of Education, 2025). The Equator Initiative (2017) emphasized that the Obudu Plateau land reclamation project shows the possibility of enhancing community-based environmental projects with mathematical modeling and AI optimization. Key Finding: Field data from Obudu (2025) shows that traditional cultures without advanced AI have ingrained optimization thinking in their behaviors. Farmers choosing seeds, fishermen exchanging information about locations, and elders forecasting weather—all of these are practiced genetic algorithms, particle swarm optimization, and neural networks without knowing their official names. The educational difficulty is not introducing new ideas but formalizing the existing ones. Adeyemi and Okonkwo (2025) argued that Nigeria can use AI to enhance scientific learning, technological innovation, and global competitiveness and tackle climate change through targeted reforms and investments. The study contends that "leveraging AI" also means leveraging old knowledge systems that have AI concepts built into them and that optimization education is available to all communities irrespective of technology availability. The integration aims at producing a generation of problem-solvers who can address 21st-century sustainability issues through the integration of climate-smart STEM education with the circular economy, math optimization and AI technologies (Economic Donut, 2023). This means in low-resource contexts merging circular economy ideas, classical optimization expertise, and mathematical formalization in climate-smart STEM education. The United Nations Office of the Special Advisor on Africa (2024) has identified the integration of STEM education as an integral part of sustainable development in local communities such as Obudu that will provide young people with skills that the communities need to adapt and be resilient to climate change. We educate AI-inspired



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optimization with local approaches to make powerful problem-solving tools accessible to everyone and to recognize indigenous knowledge systems.

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