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Designing and Fabricating an Afrocentric Agro-Machinery Learning Environment: A Case Study of Competence-Based STEM Teacher Development in Zambia

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Abstract
Competence-based STEM education requires learning environments in which learners apply knowledge to authentic problems, yet teachers often lack worked examples, fabrication facilities, and locally relevant resources. This article reports an exploratory qualitative case study of an agro-machinery learning environment co-designed by 18 educators from nine African countries during the 2026 Afrocentric Knowledge Co-Creation Programme (KCCP) at the Directorate of National Science Centre, Lusaka, Zambia. The group designed and fabricated an egg incubator, a dehuller, a grinding mill, and a pellet maker, and used them in a one-day engagement with ten Form 2 learners from Kabulonga Boys Secondary School. Data comprised daily progress reports, an open-ended questionnaire completed by the 18 educators, observation checklists, field notes, and photographs, and were analysed by deductive framework analysis. The records documented opportunities to practise measurement, geometry, heat transfer, mechanics, communication, collaboration, creativity, and problem solving. Learners proposed design modifications, including an incubator viewing window whose heat-loss trade-off was developed into a quantitative physics task. Against four operational criteria for an Afrocentric learning environment, the case met the criteria on local knowledge, local repairability, and participant agency, but met the criterion on community-expressed need only indirectly, because needs were identified from practitioners' professional experience rather than through community consultation. Machine performance was not formally tested, and competency gains were not measured. The article proposes a planning sequence for teachers and a mentorship pilot for the Kenya Science and Engineering Fair (KSEF).

Keywords: Afrocentric Education, Competence-Based STEM, Indigenous Knowledge, Engineering Design, Teacher Professional Development, Zambia

Introduction

STEM education across Africa faces the challenge of helping learners move beyond recalling scientific and mathematical concepts towards applying them to practical problems in their communities. Competence-based education (CBE) reforms respond to this challenge by calling for learning experiences that integrate knowledge, skills, attitudes, and values through meaningful tasks. In Kenya, the Basic Education Curriculum Framework organises learning around seven core competencies: communication and collaboration, critical thinking and problem solving, imagination and creativity, citizenship, digital literacy, learning to learn, and self-efficacy (Kenya Institute of Curriculum Development [KICD], 2017) [18]. In Zambia, the *2023 Zambia Education Curriculum Framework* restructured the education system from 4-7-2-3 to 3-6-4-2, replaced Grades with Forms at secondary level, and placed greater emphasis on competences and local relevance (Curriculum Development Centre [CDC], 2023) [8].

The implementation of these reforms has nonetheless been constrained. Akala (2021) [1] identifies inadequate teaching and learning resources, limited infrastructure, and uneven teacher preparedness as recurring obstacles to Kenya's Competency Based Curriculum (CBC). Studies of Zambia's competence-based curriculum report comparable difficulties in translating curriculum intentions into learner-centred, practical classroom activity (Kabombwe & Mulenga, 2019; Mulenga & Kabombwe,

2019) [16, 24]. Teachers expected to facilitate practical, integrated STEM learning therefore need documented and replicable examples of how subject knowledge, local knowledge, local materials, and community problem solving can be combined in a functioning learning environment.

Regional professional-development programmes offer one setting in which such examples can be generated. The Knowledge Co-Creation Program (KCCP) is a human-resource-development modality of the Japan International Cooperation Agency (JICA, n.d.) [15]. Since 2016, Zambia's Directorate of National Science Centre (DNSC) has hosted a JICA-supported KCCP for African educators. The 2026 programme ran from 24 May to 26 June 2026 under the theme "*Afrocentric Competence-Based STE(A)M Education Transformation for Selected African Countries*" and brought together education practitioners nominated by the Ministries of Education of 19 African countries. The first author attended as a Kenyan Physics educator nominated by the Centre for Mathematics, Science and Technology Education in Africa (CEMASTEA), which hosts the secretariat of SMASE-Africa, a network of African countries established in 2001 to strengthen mathematics and science education (SMASE-Africa, n.d.) [28]. This positioning explains the article's interest in what a Zambian-hosted, JICA-supported programme can offer Kenyan teacher development and KSEF.

Conceptual Framework: Afrocentricity, Indigenous Knowledge, and Integrated STEM

Three constructs frame the study. First, Afrocentricity, as articulated by Asante (1991) [2], is a stance that places African people and African experience at the centre of inquiry, asserting agency rather than treating African contexts as peripheral to externally derived knowledge. Afrocentricity is therefore not merely the inclusion of cultural content; it begins inquiry from African problems, resources, and ways of knowing. Second, indigenous knowledge systems (IKS) are bodies of knowledge and practice developed by communities over generations. In science education, they can be treated as legitimate sources of insight to be brought into dialogue with school science (Hewson & Ogunniyi, 2011; Ogunniyi, 2004) [14, 25]; in this case, the relevant IKS concerned poultry brooding and grain processing. Third, culturally responsive pedagogy uses learners' cultural referents to make learning meaningful (Gay, 2010) [13]. It overlaps with Afrocentricity but does not, by itself, require an African-centred epistemology.

Building on these constructs, a learning environment is judged Afrocentric in this article against four operational criteria:

(a) *Problem origin*: the problem addressed originates in a need experienced by an African community. The criterion is met **directly** when the need is expressed by community members, and **indirectly** when it is identified by African practitioners from their professional knowledge of those communities.
(b) *Knowledge base*: the design draws on African indigenous or local knowledge, not only on imported technical knowledge.
(c) *Local materials and repairability*: materials are locally accessible, and the product can be maintained and repaired locally.
(d) *Agency*: African participants set, adapt, and own the design rather than reproducing a foreign model.

The case is also situated in integrated STEM education, which Kelley and Knowles (2016) [17] describe as learning across science, technology, engineering, and mathematics that is grounded in the disciplines and situated in authentic contexts, with engineering design as a common integrator. It further draws on engineering design-based science learning, in which design tasks make scientific concepts functional (Crotty *et al*., 2017; Moore *et al*., 2014) [7, 23]. Documented, low-resource examples of Afrocentric integrated STEM in African teacher-development settings remain scarce in this literature, and it is this gap that the present case addresses.

Problem Statement and Objectives

Teachers are expected to facilitate competence-based STEM learning but often lack accessible models of how subject knowledge, local knowledge, local materials, and community problem solving can be integrated. The resource and preparedness constraints reported in Kenyan and Zambian CBE implementation (Akala, 2021; Kabombwe & Mulenga, 2019) [1, 16] make it harder for teachers to turn curriculum intentions into practical learning tasks. This article therefore examines the KCCP Agro-Machinery project as an exploratory case of how educators co-created such an environment. Its purpose is to document the development and exploratory educational use of the learning environment and to identify lessons for practical Afrocentric STEM education. The objectives are:

1. To describe the design, fabrication, functional-checking, and learner-engagement process used to develop the learning environment.
2. To identify the STEM concepts and Kenyan CBC core competencies (KICD, 2017) [18] that the documented activities created opportunities for educators and learners to practise.
3. To evaluate the learning environment against the four Afrocentric criteria.
4. To propose practical actions for adapting, evaluating, and disseminating similar learning environments, including through CEMASTEA and KSEF.

Materials and Methods

Research design

The study is an exploratory qualitative case study with design-iteration features. It is informed by design-based research (DBR) but does not claim to be DBR, because it did not include the multiple design–enactment cycles and the generation of design principles that characterise DBR (Design-Based Research Collective, 2003) [9]. The process was organised into four phases: (i) problem identification and conceptualisation; (ii) fabrication and assembly; (iii) functional checking and refinement; and (iv) learner engagement. Phase (iii) comprised one round of functional checks and adjustments during fabrication, and the learner engagement day served as a single enactment.

Positionality and reflexivity

Both authors were members of the Agro-Machinery Group, the first as a Physics educator from Kenya and the second as a host-institution participant from Zambia; we therefore report on our own collaborative work. The first author also served as the group's designated secretary and wrote the daily progress reports that form the primary record. That record is consequently an insider account and cannot be treated as an independent safeguard against insider bias.

Daily plenary sessions, at which the group reviewed the records, functioned as peer debriefing and collective validation of the account; they did not constitute member checking in the sense of returning interpretations to individual participants. No non-participant audit of the coding was undertaken, and readers should therefore treat the findings as participant-accounted rather than externally audited.

Participants and setting

The Agro-Machinery Group comprised 18 educators: 10 from Zambia and one each from Kenya, Cameroon, Eswatini, Mozambique, Namibia, Ghana, Nigeria, and Madagascar. By specialism, the group included educators in Design and Technology (4), Biology (4), Physics (4), Mathematics (3), and Agriculture (3); no Chemistry educator was a member. The group worked in four sub-teams (incubator, dehuller, grinding mill, and pellet maker) and acted as co-designers and facilitators.

Ten Form 2 learners from Kabulonga Boys Secondary School, Lusaka, took part in a one-day engagement. They were nominated by the school and accompanied by their teachers. The engagement ran from 08:00 to 18:00 (Central Africa Time) and comprised a briefing, a guided visit to the Agro Plants and Agro Animals demonstration sites, a design workshop, prototype inspection, and learner presentations with facilitator feedback. The single-sex, single-school sample limits transferability, particularly regarding gender equity in STEM.

The learning environment and fabrication process

The group fabricated four machines. The incubator responded to chick mortality, a recognised constraint in family and smallholder poultry production in Africa (Food and Agriculture Organization of the United Nations [FAO], 2014) [11], which participants identified from their professional experience. The dehuller, grinding mill, and pellet maker supported crop processing and the conversion of plant residues into animal feed. Documented materials included mild-steel angle bars, sheets and flat bars, polyurethane (PU) foam insulation, and locally sourced electrical components. Table 1 summarises the machines; to avoid presenting design intentions as achieved performance, it distinguishes configured and rated values from measured performance, none of which was recorded. Fig 1 shows the four machines and selected fabrication and engagement activities.

Table 1: Summary of the fabricated machines and their specifications

Machine	Principal features	Specifications (configured or rated values)
Egg incubator	Steel frame; walls insulated with 50 mm PU foam; locally sourced heating element; thermostat-based controller with humidifier; motorised tray turning. Design capacity of 2,112 eggs (16 trays × 132 eggs)	Controller set-points: 37.5 °C and 55% relative humidity. Tray turning: 45° either side of vertical, once every hour.
Dehuller	Abrasive dehulling chamber; hopper with feed gate; drive motor with V-belt and pulleys.	Motor rating: 3 hp (≈ 2.2 kW).
Grinding mill	Square grinding chamber with hammer blades and interchangeable screens; electric motor with belt drive.	Chamber: 300 mm × 300 mm. Motor rating: 3 hp (≈ 2.2 kW). Screen apertures: 0.8, 1.0, and 1.5 mm.
Pellet maker	Hopper; pelleting chamber with compression rollers and die plate; drive motor; gearbox and pulley system; output chute.	Drive motor rating: 10 hp (≈ 7.5 kW). Die-hole diameter: 4 mm.

Note. No throughput, temperature, humidity, or hatchability measurements were recorded (see Functional checking and refinement).

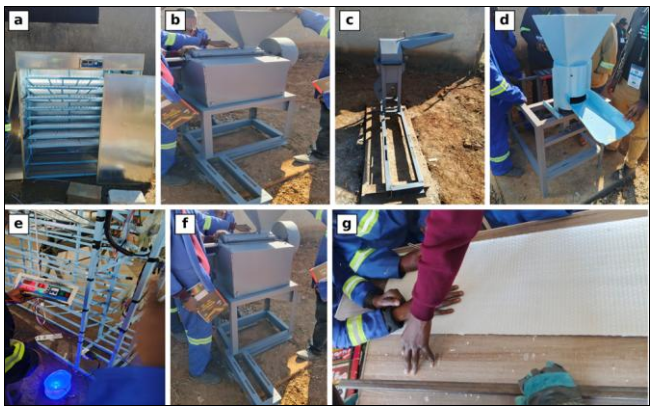


Fig 1: The Agro-Machinery learning environment. (a) Egg incubator; (b) dehuller; (c) grinding mill; (d) pellet maker; (e) incubator sub-team members testing the temperature and humidity controller and the humidifier; (f) learners describing the working of the dehuller during the engagement day; (g) learners cutting polyurethane foam insulation for the incubator walls. Photographs: Agro-Machinery Group, June 2026

Data sources and collection

Three sources informed the study. First, structured daily progress reports, written by the first author as group secretary from 13 to 25 June 2026, recorded activities, time logs, materials, challenges, and responses; the earlier weeks of the programme (24 May to 12 June 2026) were devoted to orientation, thematic sessions, and problem identification. Second, a structured KCCP questionnaire composed predominantly of open-ended items was completed by all 18 group members. It covered design principles, subject integration, learning tasks, competency development and assessment, Afrocentricity, sustainability, and enabling conditions, and it was not piloted. Third, on the learner engagement day, group members recorded observations using a simple checklist and field notes, and photographs documented participation and activities.

Data analysis and trustworthiness

The records were analysed using deductive framework analysis (Gale *et al*., 2013) [12]. The a priori framework comprised five areas derived from the study objectives and the questionnaire domains: competency opportunities, Afrocentricity and local context, interdisciplinary connections, learner engagement, and implementation challenges. Data were indexed to these areas and charted in a matrix by source, and illustrative instances were collated. Because the themes were defined in advance, the analysis is not reflexive thematic analysis in the sense described by Braun and Clarke (2021) [5].

Triangulation compared accounts across the three sources. For example, the learner-proposed incubator viewing window appeared in observation notes, photographs, and the progress report, whereas entrepreneurship claims in the questionnaire were only partly corroborated, appearing in plenary notes but not in any learner product. No inter-coder agreement procedure was applied. Table 2 presents illustrative evidence, labelled by source and role, so that readers can judge the interpretations offered in the Results and Discussion.

Table 2: Illustrative evidence by analytic area

Analytic area	Source and role	Excerpt
Competency opportunities (educators)	Progress report, 16 June 2026	"The frame was not square at first. We used the 3-4-5 method to check the corners and adjusted the angle bars until the diagonal measurements matched. The alignment problem was solved by loosening the bolts, realigning, and re-tightening."
Competency opportunities (learners)	Learner presentation notes, Group 2	"We want a small glass window on the front of the incubator so we can see the chicks hatching without opening the door. If we open the door, the heat will escape and the other eggs will get cold."
Afrocentricity and local context	Questionnaire; educator, Physics, Ghana	"The design of the incubator was informed by the way local farmers brood eggs under hens. We used the knowledge that eggs need consistent warmth for 21 days, and we set the thermostat to maintain that heat."
Interdisciplinary connections	Questionnaire; educator, Mathematics, Zambia	"I used the Pythagorean theorem to mark out the square base of the grinding mill. The students also calculated the volume of the hopper to estimate how much grain it could hold."
Learner engagement	Observation field notes; facilitator	"The learners were very active during the site visit. They asked questions about the feed and the poultry houses. When they returned to the workshop, they immediately started sketching ideas for the pellet maker and incubator."
Implementation challenges	Progress report, 18 June 2026	"There was a disagreement among the group members regarding the size of the partitions for the incubator trays. Some wanted 12 trays, others wanted 16. We resolved this by thinking analytically and critically, and agreeing on 16 trays to maximize the capacity."
Disconfirming evidence	Plenary discussion notes, 20 June 2026	"During the plenary, one learner suggested selling day-old chicks as a business. However, no written business plan or cost analysis was produced by the learners, so entrepreneurship remains a proposed idea rather than a demonstrated competency."

Ethical considerations

The study involved school learners and photographic documentation. No learner names or identifying details appear in this article, and the published photographs do not show learners' faces.

Results and Discussion

The results are presented in the order of the study objectives: the design and development process (Objective 1), the competency and concept opportunities it created (Objective 2), and the evaluation of the environment against the Afrocentric criteria (Objective 3). Implications for practice (Objective 4) are developed in the following section.

The design and development process

Idea generation with SCAMPER: During the concept phase, the group used selected SCAMPER prompts (Eberle, 1996, building on Osborn, 1963) [10, 26] as a facilitated idea-generation tool. The authors subsequently used the same prompts as an analytic lens to organise the design decisions recorded in the progress reports. Table 3 reports only those prompts for which a documented application exists.

Table 3: SCAMPER applications documented in the project

Prompt	Documented application
Substitute	Locally available mild steel substituted for imported materials.
Combine	In the pellet maker, a drive motor, gearbox, and pulley system were combined to drive the compression rollers.
Adapt	Local brooding knowledge adapted into incubator target conditions.
Modify	Pellet-maker chamber enlarged following group feedback.
Put to another use	Plant residues converted into animal feed.

Note. The prompts Eliminate and Reverse were posed as facilitation questions but produced no recorded design change and are therefore omitted.

Implementation challenges: Fabrication raised technical and interpersonal challenges, which the group resolved through discussion, iteration, and peer support (Table 4). The disagreement over tray partitions, for instance, was settled in favour of 16 trays to maximise capacity (Table 2), illustrating how design decisions were negotiated collectively.

Table 4: Implementation challenges, responses, and lessons

Challenge	Response	Lesson
Disagreement over incubator tray-partition dimensions	Discussion to consensus	Early agreement on specifications prevents rework
Frame alignment during assembly	Iterative adjustment; squaring checks	Build in verification checkpoints
Electrical integration of heater and controller	Peer support; consultation of technical references	Qualified electrical supervision is essential
Sourcing standard components (e.g., die plate, bearings)	Local fabrication and adaptation	Local repairability is a design constraint

Functional checking and refinement: Testing was limited to informal functional checks. The incubator was powered, observed to warm, and its trays were observed to turn (Fig

1a, 1e). The turning mechanism was configured to tilt the trays 45° either side of vertical once every hour, consistent with commercial hatchery guidance recommending hourly turning through approximately 38–45°, below which hatchability may decline (Aviagen, 2013; Poultry Performance Plus, n.d.) [3, 27]. The grinding mill and dehuller were run to confirm that their mechanisms turned freely. No standardised performance tests, temperature logs, hatch trials, or throughput measurements were recorded.

For reference, extension guidance for chicken eggs in forced-air incubators specifies a 21-day incubation at about 37.8 °C (100 °F), relative humidity of about 58–60% until three days before hatching and about 65% or more thereafter, and turning at least four to six times daily, with turning stopped in the final three days (Mississippi State University Extension, n.d.) [22]. The configured humidity of 55% (Table 1) is therefore slightly below this guidance and should be reviewed during future trials, in which temperature and humidity should be logged against such targets and hatchability reported. Phase (iii) thus consisted of functional verification and adjustment rather than formal testing, and no performance claims are made.

Competency opportunities

The records documented opportunities that map onto Kenya's CBC core competencies (KICD, 2017) [18]. Because educators and learners engaged with the environment in different ways, their outcomes are reported separately.

Educators: During fabrication, educators used the 3–4–5 Pythagorean method to square frame layouts and resolved alignment problems during assembly (Table 2), which are instances of critical thinking and problem solving. Sub-team work and plenary presentations provided instances of communication and collaboration, and the testing of the incubator controller and humidifier (Fig 1e) required the application of thermal and electrical concepts.

Learners: Learners proposed adding a viewing window to the incubator so that they could observe hatching without opening the door and losing heat (Table 2). Facilitators used the proposal as a teaching point because it involves an explicit physics trade-off, developed in the next subsection. Learners also explained the working of the machines to their peers (Fig 1f), took part in fabrication tasks such as cutting insulation (Fig 1g), and sketched their own incubator and pellet-maker concepts. When invited to consider livelihoods, they proposed selling day-old chicks or animal feed; because no learner product corroborated this idea (Table 2), entrepreneurship is reported as an opportunity prompted by facilitation rather than as a demonstrated competence, and leadership is not claimed. No pre- or post-assessments were conducted, so the evidence documents opportunities and observed participation, not competency gains.

A physics teaching point: the heat-loss cost of a viewing window

The learners' proposal can be developed into a quantitative task for physics teacher development. Steady-state heat loss through a wall element is $Q = UA\Delta T$, where the overall heat-transfer coefficient U combines the convective resistances of the inner and outer surfaces with the conductive resistance of the wall, $1/U = 1/h_i + L/k + 1/h_o$ (Bergman *et al*., 2011) [4].

For the built unit, consider the viewing window of 0.20 m × 0.30 m (A = 0.06 m^2), an internal temperature of 37.5 °C, and an ambient temperature of 25 °C (ΔT = 12.5 K). Assume surface coefficients $h_i = h_o$ = 8 W m^{-2} K^{-1}, which lies within the typical range for free convection in air, and representative conductivities of 1.4 W m^{-1} K^{-1} for plate glass and 0.026 W m^{-1} K^{-1} for rigid polyurethane foam (Bergman *et al*., 2011) [4]. For 4 mm single glazing, $U \approx$ 3.95 W m^{-2} K^{-1} and $Q \approx$ 3.0 W; for the 50 mm of PU foam that the window replaces, $U \approx$ 0.46 W m^{-2} K^{-1} and $Q \approx$ 0.35 W. The window therefore loses roughly eight to nine times as much heat as the foam it replaces, an additional loss of about 2.6 W.

This additional loss is small relative to the likely loss of warm, humid air each time the door is opened, which supports the learners' reasoning; learners could test this comparison by estimating door-opening losses from the cabinet's air volume. The task can be extended by comparing double glazing or varying the window area. Because these figures are estimates based on assumed coefficients rather than measurements, they are best used as a modelling exercise that learners can later verify with temperature logging.

Interdisciplinary integration

The heat-loss task illustrates a broader pattern: each machine connected concepts across several learning areas. Table 5 summarises these links. Because no Chemistry educator was in the group, the Chemistry links are presented as potential curriculum connections identified by the authors rather than as links documented during the project.

Table 5: Interdisciplinary links between learning areas and the Agro-Machinery project

Learning area	Connection to the project	Specific concepts
Physics	Incubator thermal design; drive mechanisms; electrical control	Conduction, convection, and radiation; thermal insulation and U-values; negative-feedback temperature control (thermostat/relay); gear and pulley ratios, torque, and mechanical advantage; electrical power and efficiency
Biology	Embryonic development; animal nutrition	Incubation period and conditions; feed formulation; conversion of crop residues into feed
Mathematics	Measurement; layout; capacity	Pythagorean theorem in squaring frames; geometry; volume and capacity calculations
Agriculture	Poultry and maize systems	Smallholder poultry production; maize processing; residue utilisation
Design and Technology	Fabrication process	Technical drawing; measuring and marking out; joining (welding, bolting); workshop safety
Chemistry (potential)	Materials and feed	Composition and nutritional value of feeds; corrosion of mild steel and surface protection

Learner engagement and experiential learning

The structure of the engagement day also shaped the learning opportunities. Learners visited the Agro Plants and Agro Animals demonstration sites before designing machines related to the needs they had observed, for example linking crop residues to pelletised animal feed. The sequence maps onto Kolb's (1984) [21] experiential learning cycle: the site visit and workshop inspection constituted

concrete experience; learner discussion of what they had observed constituted *reflective observation*; facilitator-led explanation of incubation and feed principles constituted *abstract conceptualisation*; and learners' concept sketches constituted *active experimentation*, limited within a single day to design rather than testing. The evidence indicates active participation, not long-term retention or transfer.

Evaluation against the Afrocentric criteria

Turning to the third objective, Table 6 applies the four operational criteria defined in the conceptual framework to the case.

Table 6: Evaluation of the learning environment against the Afrocentric criteria

Criterion	Judgement	Evidence and qualification
(a) Problem origin	Met indirectly	Chick mortality and crop-residue use were identified from participants' professional knowledge of smallholder farming and prioritised over other candidate designs. Community members were not consulted during the programme.
(b) Knowledge base	Met	The community practice of hens brooding eggs for 21 days with consistent warmth informed the decision to use a thermostat-controlled heating element configured to 37.5 °C and 55% relative humidity (Tables 1 and 2). The conditions achieved were not logged.
(c) Local materials and repairability	Met	Mild steel and locally sourced electrical components were chosen explicitly so that the machines could be repaired locally.
(d) Agency	Met	Educators set and adapted the designs, and learners proposed modifications and their own concepts.

Local problems and local materials alone would describe any place-based STEM project. What distinguishes this case is the deliberate use of community-held brooding and processing knowledge as a design input, together with the explicit criterion of local repairability, in place of the importation of a finished foreign design. Because criterion (a) was met only indirectly, however, the Afrocentric claim is partial. Future iterations should include community consultation, for example with smallholder poultry keepers, before the problem-definition phase.

Implications for Practice

A planning sequence for classroom practice

Addressing the fourth objective, the project suggests a seven-step planning sequence that combines an engineering design process with an instructional framework. The steps correspond to the engineering design elements of problem definition, background research, planning, implementation, testing, and communication identified by Moore *et al.* (2014) [23], and for lesson planning they can be placed within the BSCS 5E instructional model (Bybee *et al.*, 2006) [6]. The 5E model is an instructional model for sequencing science teaching rather than an engineering design model; Table 7 shows how the two frameworks align.

Table 7: Planning sequence mapped to engineering design elements and the 5E instructional model

S. No	Planning step	Engineering design element	5E phase
1	Begin with a locally experienced problem	Problem definition	Engage
2	Investigate the context and available resources	Background research	Explore
3	Identify relevant concepts across learning areas	Background research; planning	Explain
4	Generate and compare design ideas	Planning	Elaborate
5	Construct a prototype	Implementation	Elaborate
6	Test against explicit criteria and refine	Testing and evaluation	Elaborate; Evaluate
7	Communicate findings and improvements	Communication	Evaluate

Assessment within this sequence can combine design sketches, calculations such as the heat-loss estimate above, observation checklists, learner explanations, teamwork reflections, and prototype-test evidence, making both process and product visible.

Implications for the Kenya Science and Engineering Fair

KSEF operates under Kenya's Ministry of Education. Its rules require participants to be registered Kenyan students under 20 years of age, with projects reviewed and approved by a Scientific Review Committee (KSEF, 2025) [19]. Separate score sheets are used for junior and senior categories; in the non-robotics categories, the written report is assessed on background research, aims, hypotheses or objectives, methods and materials, variables, results, analysis and discussion, and references, while oral communication is assessed on enthusiasm, voice and tone, self-confidence, scientific language, and responses to questions (KSEF, 2026) [20].

These criteria reward a well-documented final product but give little explicit weight to the formative, iterative design work that this project illustrates. A potential next step is therefore a CEMASTEA-supported mentorship arrangement in which teachers and learners jointly develop projects from community needs, document their design iterations, and apply safety and performance criteria. This is a proposed direction rather than an established outcome of the project; any pilot should specify participating schools, mentor responsibilities, resources, rubrics, timelines, and impact indicators.

Safety considerations for school use

Any school adaptation of this environment must provide qualified supervision and address mains-voltage safety (earthing, enclosed wiring, and residual-current protection), the guarding of moving parts on the grinding mill, dehuller, and pellet maker, and clearly defined learner roles that exclude hazardous operations such as welding and unsupervised machine operation.

Limitations

This article is based on project records, a self-report questionnaire, and documentation of a single engagement

day with ten boys at one school. Six specific limitations should be noted:

1. The primary record was written by the first author, an insider, and no inter-coder agreement procedure was applied.
2. Findings may not transfer from a well-resourced national science-centre workshop to typical schools.
3. The questionnaire relied on self-report and was not piloted.
4. There were no participant-level assessments, baseline or follow-up measures, quantified costs, or standardised performance results.

The findings are therefore context-specific and exploratory.

Conclusion and Recommendations

The 2026 KCCP Agro-Machinery project illustrates how competence-based STEM teacher development can be organised around locally relevant agricultural problems, with local knowledge and local materials treated as design inputs rather than cultural additions. Its distinctive contribution is a documented template, with explicit Afrocentric criteria, for organising integrated STEM around local problems under resource constraints, together with a transparent account of where the case falls short. The evidence does not establish measured competency gains or verified machine performance; establishing these is the task of future, more systematic iterations. To that end, the following actions are recommended:

1. Strengthen workshop infrastructure and access to tools, local materials, and qualified technical supervision.
2. Develop and document standard procedures for machine safety, testing (including temperature and humidity logging and hatch trials), maintenance, cost estimation, and performance evaluation.
3. Formalise partnerships among schools, communities, technical experts, and CEMASTEA to support mentorship and locally relevant project development.
4. Pilot a CEMASTEA-supported mentorship model for KSEF with clear objectives, assessment rubrics, and evaluation indicators.
5. Document and disseminate evaluated Afrocentric STEM case studies through the SMASE-Africa network, including evidence of learner outcomes and implementation costs.

Declarations

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Data availability: The anonymised daily progress reports (13–25 June 2026) and the KCCP questionnaire instrument are available from the corresponding author on reasonable request, subject to the conditions of the institutional authorisation granted by the National Science Centre, Zambia. No learner-level data are available, because no learner-level assessments were conducted and identifiable learner information is protected by the consent and assent conditions described under Ethical considerations.

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