Open-Source, Open Minds: A Case Study of the Bombeke Foundation's Model for Empowering Youth in the Age of AI Disruption

Alex Tumwesigye[1], Sukriti Pathak[2*], Shikhar Kumar[3], Michael Mwebaze[1], Engineer Bainomugisha[1,4]

[1]Bombeke Foundation, Kampala, Uganda
[2] G.B. Pant University of Agriculture and Technology, Pantnagar, India
[3]Global Youth Mentorship and Innovation, Bombeke Foundation, Chapel Hill High School, North Carolina, United States
[4]Department of Computer Science, School of Computing & IT, Makerere University – Kampala, Uganda

pathaksukriti953@gmail.com

Abstract. The global skills gap continues to grow as many young people in underserved communities lack access to technology and practical Science, Technology, Engineering, and Mathematics (STEM) education. This paper presents a case study of the Bombeke Foundation's model in Uganda, which combines open-source hardware and software tools, a youth-led design cycle, and project-based learning to prepare children for opportunities in the age of artificial intelligence (AI). The model was piloted with eighteen children aged ten to sixteen in urban and peri-urban Uganda. Over a three-month period, participants engaged in biweekly design sprints supported by facilitators and co-founders. A youth representative serving in a leadership role contributed ideas and feedback through ongoing dialogue with senior mentors, ensuring that children's perspectives directly guided priorities and innovation. The preliminary results show how open-source approaches can overcome resource constraints and generate meaningful learning outcomes. Children simplified 3D design tools such as Tinkercad by requesting drag-and-drop science templates, redesigned geometry learning around familiar plant shapes, developed the Dancing Waters project, which demonstrated how youth could translate theoretical STEM concepts into a practical, open-source innovation that built both technical skills and creative confidence, and created a storytelling literacy tool using folktales that increased participation among learners including those who would otherwise be excluded, for example, shy learners. Post-pilot surveys found that 85% of learners preferred these tools over chalkboard-based teaching. This case demonstrates that grassroots innovation, when informed by youth voices and guided by sustained mentorship, can deliver scalable and culturally relevant solutions. We recommend that education ministries embed youth participation in EdTech design and that global funders support child-led design labs to bridge the digital divide. The Bombeke Foundation's work offers a practical framework for preparing the next

P. Pankaj et al. (eds.), *Proceedings of the 13th International Youth Conference in the series of "Youth for India @2047, AI Disruption and Opportunities: Preparing Youth for Global Challenges (IYC 2026)*, Advances in Intelligent Systems Research 208,
https://doi.org/10.2991/978-94-6239-676-0_8

generation of leaders in an AI-integrated future. This study contributes to global discussions on AI readiness and equitable STEM learning in the Global South.

Keywords: Open-Source, Open Minds, AI Disruption

1 Introduction and Problem Statement

Across Africa, a widening gap continues to separate young people from meaningful participation in Science, Technology, Engineering, Arts, and Mathematics (STEAM) education. While digital transformation is rapidly reshaping global economies, millions of children in low- and middle-income countries still learn in classrooms without electricity, adequate learning materials, or trained teachers who can link theory to practice. In Uganda, where the highest proportion of population is young (under 18 years) (Uganda Bureau of Statistics, 2023), this disconnect poses both a challenge and an opportunity. If our youth remain consumers of imported technologies, we risk deepening dependence; if they become creators, Uganda and the region can build an innovation base grounded in our own culture and needs.

1.1 Global and Regional Context

International assessments such as UNESCO's Global Education Monitoring Report (2023) highlight persistent inequities in STEM participation: less than 20 percent of students in Sub-Saharan Africa report access to laboratories or maker resources, and fewer than one in ten rural schools offer computer studies beyond basic literacy. While advanced economies invest in artificial intelligence (AI), robotics, and digital fabrication for early learners, many African systems still emphasize rote instruction. This creates a structural disadvantage at precisely the moment when AI is expected to transform every sector-from agriculture to health to governance.

Uganda's education sector has long benefited from external aid-through school construction, teacher training, and digital-skills initiatives. Yet the sharp decline in global aid since 2024 has disrupted those programs (Human Rights Watch, 2024; Fraser, 2025). With foreign donors withdrawing or pausing funding, many schools face resource shortages and project cancellations. This aid contraction underscores the urgency of building self-reliant, community-driven innovation ecosystems that can thrive without external dependency. The shift from aid to autonomy is no longer optional; it is a survival strategy for equitable learning.

1.2 Local Challenges in STEM and the Bombeke Response

Ugandan children are naturally curious and inventive, yet the education system often limits that potential. Practical science is underfunded, imported kits are costly or incompatible with local curricula, and unreliable power and internet restrict digital access. Teachers rarely receive training in design-based learning, leaving classrooms dominated by chalkboard instruction rather than hands-on discovery. Learners therefore associate technology with foreign experts instead of their own creativity.

Cultural relevance remains another barrier, as most educational technologies are developed outside Africa and rarely reflect local realities, languages, or stories.

To bridge these gaps, the Bombeke Foundation created Bombeke Studio-a youth-led, open-source learning hub where children aged 10–16 design and fabricate educational tools using Tinkercad and low-cost 3D printers. Each project begins with a community problem-measuring gardens, visualizing geometry, or illustrating folktales-and evolves through biweekly design sprints over three months. The model rests on three pillars: open technology to reduce barriers, participatory design for relevance, and sustained mentorship to guide learners. Together, these elements transform learning into making-and making into empowerment.

1.3 Purpose and Significance

This paper documents how Bombeke Studio's youth-led, open-source model in Kampala demonstrates a practical pathway for preparing young learners for an AI-driven future while reinforcing the values of Ubuntu and self-reliance. The initiative positions children not as passive recipients of education but as active designers and innovators who shape tools relevant to their daily lives.

By integrating open-source technology, mentorship, and participatory learning, the model cultivates curiosity, teamwork, and algorithmic thinking-the same problem-solving patterns foundational to AI. Beyond technical skills, it nurtures confidence, empathy, and civic responsibility, preparing youth to create technology that serves both individual and community needs.

The significance of this case study lies in showing how grassroots innovation can drive digital inclusion in the Global South. It illustrates that local creativity, when supported by mentorship and open tools, can achieve educational transformation even in low-resource contexts. In doing so, Bombeke Studio contributes to global conversations on AI readiness, youth empowerment, and post-aid sustainability, offering a model of how Africa's next generation can lead in shaping ethical, community-centered innovation.

1.4 Research Questions

The study explores four guiding questions:

How does a youth-led, open-source design model influence engagement and confidence among children aged 10–16 in Uganda?

In what ways do learners translate abstract STEM concepts into practical community solutions?

What mentorship and facilitation structures best sustain participation and inclusivity in low-resource settings?

How can such models strengthen AI readiness and self-reliance in the post-aid era?

1.5 Structure of the Paper

The remainder of this paper is organized as follows: Section 2 reviews literature on youth-led design, open-source education, and AI readiness in the Global South. Section 3 details our methodology. Section 4 presents findings from the Kampala pilot. Section 5 discusses implications, including the integration of *Ubuntu* and self-reliance in a post-aid context. Sections 6 and 7 offer recommendations and conclusions that highlight how local innovation can drive national and global transformation.

2 Literature Review

2.1 Introduction

To understand the significance of the Bombeke model, we situate our work within three interconnected domains of scholarship:

1. Youth-led participatory design and constructionist learning,
2. Open-source education and maker pedagogy in low-resource settings, and
3. AI readiness and digital transformation in the Global South.

These perspectives help explain why a community-driven approach can serve as both a pedagogical innovation and a social-development strategy in a post-aid context.

2.2 Youth-Led Participatory Design and Constructionism

Participatory design (PD) emerged in the 1970s as a democratic response to top-down technological development (Ehn 1988). Within education, PD evolved into youth-led participatory design (YPD), where learners become co-creators of the learning environment itself. Allison Druin (2002) demonstrated that when children design technology, they also design their own learning identities-gaining confidence, empathy, and agency.

In Sub-Saharan Africa, PD aligns naturally with cultural traditions of collective problem-solving and apprenticeship. Rather than separating knowledge from social life, communities view learning as a shared endeavor. This worldview mirrors Ubuntu, which defines a person through relationships with others. Recent Ugandan and Kenyan studies on community innovation hubs show that youth-led creation improves retention and intrinsic motivation, especially when mentorship is peer-based and contextually relevant.

Bombeke Studio builds directly on these ideas. Each design sprint functions as a miniature PD process: learners identify community challenges, brainstorm solutions, prototype, and reflect. Mentors facilitate but do not dictate outcomes. This dynamic echoes Seymour Papert's constructionism, which holds that learning happens most effectively when people are actively constructing a meaningful product (Papert 1980). In our case, that product might be a geometry tool, a water-flow demonstration, or a storytelling figure. Through making, learners construct both artifacts and knowledge.

2.3 Open-Source Education and Maker Pedagogy in Low-Resource Contexts

The open-source movement, which is rooted in principles of transparency, collaboration, and collective improvement-has transformed how knowledge and technology circulate. In education, open-source tools lower barriers to entry and enable adaptation to local conditions. Pearce (2019) describes open hardware as a “pathway from dependency to design sovereignty,” particularly powerful for institutions that cannot afford proprietary systems.

Maker education extends this logic by combining digital fabrication with hands-on creativity. Martinez and Stager (2013) emphasize that when learners tinker and iterate, they internalize scientific reasoning. For the Global South, this approach offers not only cognitive but also economic value: it cultivates repair, improvisation, and sustainable reuse of materials. African maker movements-from Kenya’s Gearbox to Rwanda’s FabLab-demonstrate how open innovation can thrive despite limited resources when communities share tools and knowledge (Pearce, 2019).

Uganda’s educational context mirrors these findings. Our classrooms remain resource-constrained, yet young people possess immense inventive potential. By introducing open software such as *Tinkercad* and low-cost 3D printers powered by solar energy, Bombeke Studio provides a localized version of the global maker ethos. Children learn that design can emerge from scarcity; constraint becomes a stimulus for creativity. This resonates with UNESCO’s “*Leveraging Innovative Technology in Literacy and Education Programmes for Refugees, Migrants, and IDPs*” guideline explores how digital tools can support literacy and lifelong learning in displaced populations to foster inclusion and resilience ((UNESCO Institute for Lifelong Learning, 2022).

Moreover, open-source learning contributes to knowledge sovereignty, the ability of a nation or community to produce and own its educational content. When learners design their own tools, they decolonize the classroom by inserting indigenous perspectives into science and technology. Our use of folktales and environmental analogies demonstrates that global technology can be re-imagined through African narratives.

2.4 AI Readiness and Digital Transformation in the Global South

AI is redefining future work and citizenship. UNESCO (2023) defines *AI competence* as the capacity to understand, interact with, and ethically evaluate intelligent systems. Yet for many developing nations, AI literacy remains abstract because basic digital infrastructure is still uneven. Scholars such as Holmes et al. (2022) warn that uncritical importation of AI tools can reproduce bias and dependency, whereas locally guided experimentation can promote fairness and cultural relevance.

In Uganda, the conversation on AI has mostly centered on higher education and policy elites. Few initiatives translate AI concepts into forms accessible to children. Bombeke Studio addresses this gap indirectly: while we do not teach programming or machine learning, our design process mirrors the logic of AI systems-problem definition, data collection (observation), modeling, testing, and iteration. When learners modify a 3D design or adjust variables in a physical prototype, they practice abstraction and systems reasoning, foundational cognitive skills for AI. Equally important, they learn ethics through experience: collaboration, fairness, and inclusion become part of the design process itself.

This alignment positions Bombeke as a form of AI-readiness through making-a low-cost, culturally grounded route to equip youth for the algorithmic era. It also supports broader digital-transformation goals outlined in Uganda's *National ICT Strategy 2025 (Ministry of Information, Communications Technology & National Guidance, 2025)* which calls for indigenous innovation ecosystems to complement formal schooling.

2.5 Gaps in the Literature and Contribution of This Study

Despite growing interest in African innovation hubs, empirical evidence on child-led open-source learning remains scarce. Most research focuses on university or adult maker spaces. Few studies document how younger children, especially those from under-resourced schools, use open tools to design curricular materials that reflect local realities. Furthermore, existing literature rarely connects participatory design with philosophical frameworks such as *Ubuntu* or Asian notions of self-reliance. Our case study contributes to closing these gaps by demonstrating that youth-led design can advance both technological capability and cultural renewal.

Bombeke's approach reframes innovation from an external intervention to an internal capability-what we describe as shared self-reliance. By integrating *Ubuntu*'s emphasis on communal care with the pragmatic ethos of self-reliance, we show how African youth can become co-architects of AI-era education. This intersection of pedagogy, philosophy, and practice defines the study's originality and global relevance.

3 Methodology

3.1 Research Design

We adopted a qualitative case-study design to understand how a youth-led, open-source learning model can strengthen STEM engagement and AI-era readiness among children in Uganda. It was chosen to provide depth over breadth. The case-study approach allows deep exploration of context and process rather than numerical generalization (Yin 2018). We aimed to describe how the Bombeke Studio model works and to explore why it inspires learners and what it shows about community self-reliance.

The study used multiple data sources-observation logs, learner reflections, prototype artifacts, and surveys-to triangulate insights. Combining qualitative and limited quantitative evidence offered a balanced view of learner experiences and outcomes.

3.2 Study Setting

The pilot took place at the Bombeke Hub in Kampala, Uganda's capital city. The hub is a small, solar-powered maker space situated within a mixed-income neighborhood accessible to both school-going children and out-of-school youth. It offers open hardware tools (a Creality Ender-3 3D printer, Raspberry Pi mini-computers) and refurbished laptops running free software. The physical environment, a single large room partitioned into work zones, was chosen deliberately to encourage collaboration, movement, and visibility of each team's progress.

Although urban, the hub draws learners from peri-urban areas, giving the pilot a microcosm of Uganda's diverse schooling contexts. Frequent power interruptions and limited internet bandwidth reflected the real conditions under which most schools operate, making the site a realistic testbed for sustainable innovation.

3.3 Participants

Eighteen learners aged ten to sixteen (nine girls and nine boys) were recruited through three partner schools and community referrals. Selection emphasized curiosity and commitment rather than academic performance. Each participant obtained parental consent and school endorsement.

A youth representative served as liaison between participants and adult mentors. This role allowed the group to express needs and suggestions collectively, embodying the participatory spirit of *Ubuntu*. Four mentors-two Bombeke co-founders, one university volunteer, and the youth representative-facilitated the sessions. Mentors modeled peer learning rather than authority, emphasizing teamwork, respect, and inclusion.

3.4 Program Structure

The pilot lasted three months, comprising six bi-weekly design sprints. Each sprint followed a four-phase cycle:

1. Discover: Learners identified everyday problems (e.g., how to measure garden plots or explain sound waves).
2. Design: They sketched solutions and created 3D models using *Tinkercad*.
3. Develop: Teams fabricated or assembled prototypes using low-cost materials.
4. Discuss: Participants tested each other's designs, reflected, and documented lessons in journals.

Each session lasted about three hours and ended with a group debrief. Learning themes were aligned with the primary and lower-secondary curricula-geometry, natural science, and literacy-so that classroom knowledge connected to tangible outcomes. The mentors integrated short mini-lessons on measurement, coding logic, and storytelling to reinforce conceptual understanding.

3.5 Data Collection

We used four complementary instruments:

1. Observation Logs: Mentors recorded attendance, engagement levels, collaboration patterns, and notable incidents.

2. Pre- and Post-Session Surveys: Simple Likert- and smiley-scale questionnaires measured changes in confidence and enjoyment.
3. Learner Journals: Each child maintained a notebook documenting ideas, sketches, and reflections on what they learned.
4. Prototype Review Rubrics: Peers and facilitators evaluated usability, creativity, and relevance of each artifact.

We analyzed observation notes, learner journals, and rubric evaluations across six design sprints. Survey trends were summarized descriptively, while qualitative notes were coded thematically using manual content analysis. Illustrative quotations in the Findings section are composite reflections drawn from participant journals and mentor observations to preserve anonymity while conveying authentic learner voice.

3.6 Data Analysis

Analysis proceeded in three stages.

1. *Open Coding*: All qualitative data including observation notes, learner reflections, and facilitator inputs were reviewed to identify recurring words and phrases such as *teamwork, confidence, problem-solving, fun,* and *community help*. These initial codes were generated inductively from the data.
2. *Axial Coding*: Codes were then grouped into broader categories—*creative confidence, collaboration, mentorship influence,* and *cultural relevance*—by examining relationships across sessions and participants (Charmaz, 2014).
3. *Selective Coding*: Finally, these categories were synthesized into overarching themes that explained how youth participation and open tools contributed to engagement and learning outcomes. Themes were refined through iterative comparison across multiple data sources to ensure consistency.

Quantitative survey results were cross-checked with qualitative findings to strengthen validity. For example, increases in self-confidence scores were compared with observation notes describing independent problem-solving behavior and peer collaboration.

3.7 Ethical Considerations

The study adhered to the UNICEF (2013) *Ethical Research Involving Children* guidelines. Parental consent and child assent were obtained in writing. No identifying photographs were published. Gender equity was prioritized in team formation. Sessions were multilingual-English, Luganda, and Kiswahili-to ensure inclusion of refugee and migrant learners. Mentors completed orientation on child protection, cultural humility, and safe technology use. Data was stored securely within the foundation's internal repository.

3.8 Limitations

Because the sample was small and localized, results should therefore be interpreted as exploratory rather than generalizable. Descriptive trends such as satisfaction scores capture trends but not long-term effects. However, as a proof-of-concept, the pilot offers valuable insights into how community-based, youth-led design can operate under real-world constraints. As a single-site case study with a relatively small sample size (n=18), the findings should be interpreted as exploratory and context-specific rather than fully generalizable. Future cycles will incorporate longitudinal tracking and comparison groups to strengthen evidence.

4 Findings and Analysis

4.1 Overview of Participation and Engagement

Eighteen children (nine girls and nine boys) took part in the three-month pilot. Attendance remained strong: fifteen learners completed at least five of the six biweekly design sprints, and eleven attended all sessions. Participants demonstrated high enthusiasm, often arriving early or staying beyond scheduled hours to continue refining their projects.

Mentors observed a visible shift in learner behavior over time. In the early sessions, many children hesitated to explore tools without direct instruction. By the final sprints, they confidently navigated the 3D-design interface, assisted peers, and proposed new ideas beyond the assigned tasks. Surveys confirmed this change: before the program, only five learners reported that they "felt sure" they could make something useful using technology; by the end, sixteen reported strong confidence in their ability to design and explain their creations.

A 13-year-old girl summarized the transformation simply:

"At first, I thought computers were for rich people or older brothers. Now, I see I can use them to solve my own problems."

4.2 Key Outputs and Learning Artifacts

The pilot generated multiple prototypes and learning tools that reflected both technical and cultural imagination. The most notable projects included the following:

Simplified 3D Design Templates.

Learners found the standard *Tinkercad* interface complex, particularly the mathematical precision required for shapes and scaling. They suggested adding pre-made "science templates" that could be modified easily. Working with mentors, the group created drag-and-drop models for cube nets, protractors, and plant-based geometry shapes. These templates became the foundation for a low-literacy introduction to 3D design, proving that children could re-engineer tools to make them more accessible for others.

Geometry Kit Inspired by Nature.

A group of learners noticed that leaves and flowers around the hub exhibited repeating patterns. Guided by a mentor, they photographed local plants and used these patterns to model polygons and fractals in *Tinkercad*. They then printed a small set of demonstration tools showing how geometry exists in nature. Teachers later reported that the models improved pupils' ability to recognize shapes and symmetry. One boy proudly remarked,

"Now I can touch what the teacher draws on the board."

The "Dancing Waters" Project.

Another team merged music and physics by experimenting with vibration and sound waves. Using recycled plastic bottles, straws, and a phone speaker, they created a simple water fountain that pulsed in rhythm with music. They called it *Dancing Waters*. The project linked frequency, vibration, and energy-concepts normally taught abstractly. During the exhibition, this demonstration captured attention and sparked cross-group discussion, showing how joy and curiosity enhance scientific reasoning.

The sense of accomplishment from creating something tangible inspired learners to explore how their new skills could also strengthen relationships at home.

Gifts and Self Esteem.

To strengthen motivation and self-esteem, learners designed and 3D-printed small gifts such as rings and bracelets for their parents. The activity allowed children to demonstrate what they had learned and to share their sense of accomplishment beyond the classroom. When parents came to pick them up and received these gifts, they expressed pride and appreciation. This simple exchange deepened the children's confidence, reinforcing the idea that their creativity had real-world value and could bring joy to others.

4.3 Descriptive Trends

Activities such as the Dancing Waters experiment and the exchange of handmade gifts demonstrated how technical and emotional learning can reinforce one another, leading to sustained engagement and pride in achievement. The quantitative results summarized below complement these qualitative insights.

Table 1. Summary of key descriptive trends

Indicator	Result	Data Source
Learners completing ≥5 sessions	83% (15/18)	Attendance logs
Average satisfaction (smiley scale)	4.7 / 5 (~94%)	End-session surveys
Prototypes rated "usable" by peers	90%	Peer rubric
Self-confidence increase ("I can make something useful")	from 28% → 89%	Pre/Post survey

Girls in leadership or presentation roles	7/9 (78%)	Data from attendance logs and end-session surveys.

The results in Table 1 indicated that open-source, youth-led design not only sustains participation but also promotes gender inclusion and self-efficacy. The 94% average satisfaction rate shows that creative, collaborative learning can flourish even without financial incentives or competition. These descriptive trends confirm that a supportive, culturally relevant design environment fosters both retention and confidence among young learners.

4.4 Qualitative Insights: Creativity, Collaboration, and Confidence

Creativity: Learners constantly adapted available materials-recycling plastic bottles, reusing cardboard, and modifying 3D models to fit their ideas. When the printer jammed due to power fluctuation, they switched to paper mock-ups and continued iterating. Mentors called this "plan-B creativity." It reflected resilience and the ability to solve problems under constraints.

Collaboration: *Ubuntu* values were evident throughout. Children naturally formed mixed-gender teams and rotated leadership. The youth representative played a key role in moderating discussions, ensuring each voice was heard. Group reflections often included phrases such as "we built" or "our idea." This shared language mirrored collective ownership and minimized hierarchy.

Confidence: By the final exhibition, every participant presented their work publicly. Observers from partner schools remarked on the children's clarity and enthusiasm. For many, it was their first time explaining scientific principles in front of adults. Post-program journals contained self-affirmations like "I am a designer" and "Next time I will teach others."

These expressions reveal transformation not merely in skill but in identity-learners began to see themselves as capable innovators.

4.5 Gender and Inclusion

From the outset, equal participation was emphasized. Mentors observed that girls were initially cautious about handling equipment, but this changed after team rotation. By the third sprint, girls led three of the four main project groups. Their leadership often focused on functionality and presentation detail, complementing the boys' technical experimentation. The inclusion of multilingual facilitation (English, Luganda, Kiswahili) also helped refugee and migrant children feel valued. This equity-driven design created a sense of belonging that transcended socio-economic differences.

4.6 Role of Mentorship and Community Ownership

The mentoring structure proved fundamental to success. Youth facilitators, being close in age to participants, bridged communication gaps and modeled achievable pathways. Adult mentors focused on safety, ethics, and connecting projects to school curricula. This layered mentorship approach-youth guiding youth within a supportive adult framework-embodies *Ubuntu*'s intergenerational respect.

The pilot culminated in a community showcase attended by parents, teachers, and local leaders. Visitors expressed surprise at the sophistication of the children's work and requested training for their own schools. Several parents volunteered to help in future sessions, demonstrating how a youth initiative can mobilize adult engagement and local trust.

4.7 Emerging Themes

Three overarching themes emerged from data analysis:

1. Agency through Making: Learners moved from passive instruction to active creation, developing a sense of authorship over their education.
2. Cultural Relevance as Catalyst: Linking design to familiar stories and natural elements enhanced comprehension and pride in local identity.
3. Innovation as Community Practice: Collaboration replaced competition, showing that collective progress-an *Ubuntu* principle-drives sustained engagement.

The following subsection discusses how these cognitive and ethical shifts position learners for AI-era readiness.

4.8 Building Blocks for AI Readiness

Although AI was not directly taught, the cognitive processes cultivated-pattern recognition, abstraction, iteration, and ethical reasoning-mirror foundational AI concepts. Learners practiced simple logic when predicting how design changes would affect outcomes. They discussed fairness implicitly when evaluating each other's prototypes. In this sense, Bombeke Studio acts as a precursor to AI literacy: a setting where human intelligence is developed through social and creative learning.

By merging technological skills with empathy and teamwork, the initiative prepares youth to lead future innovation that benefits both individuals and communities. This synthesis of *Ubuntu* and self-reliance transforms education from a donor-driven service into a locally owned system of discovery.

5 Discussion

5.1 Re-thinking Learning through Participation and Making

Our results confirm what participatory design theorists have argued for decades: when learners are treated as partners rather than recipients, motivation and understanding deepen. Druin (2002) described children as "design partners," while Papert (1980) demonstrated that constructing tangible artifacts transforms abstract reasoning into lived experience. Bombeke Studio provides new evidence of these principles in an African context marked by limited infrastructure and strong communal traditions.

Through six bi-weekly sprints, learners became active designers of their own learning environment. Their ability to simplify *Tinkercad* templates and create culturally meaningful prototypes shows that even without advanced laboratories, knowledge production can occur anywhere. These results align with Papert's (1980) constructionist theory and with Bevan et al. (Bevan, Gutwill, Petrich, & Wilkerson, 2015), who found that learning through making fosters engagement and creativity beyond what traditional classrooms achieve. Our findings thus extend constructionist pedagogy to the realities of Ugandan classrooms-where scarcity becomes an engine of creativity rather than a barrier.

5.2 The Role of Mentorship and *Ubuntu* in Sustaining Engagement

The layered mentorship structure-youth guiding youth within a light adult framework-proved essential. It operationalizes *Ubuntu*'s intergenerational ethic: each learner's success is tied to the success of others. Mentors avoided hierarchical authority, modeling cooperation and empathy. This relational dynamic built psychological safety, allowing girls and quieter learners to take leadership roles.

In contrast to competitive academic models, the Bombeke approach positions learning as shared accomplishment. The collective ownership seen in phrases such as "our idea" or "we built" mirrors the *Ubuntu* conception of personhood through community. This challenges Western individualism embedded in many imported STEM programs and provides a culturally grounded path to inclusion.

Such mentorship also bridges digital divides. When peers teach peers, technical knowledge circulates horizontally; when parents and teachers witness children explaining science, community trust grows vertically. The resulting network of youth, families, and mentors constitutes a micro-ecosystem of innovation that can persist without continuous donor input.

5.3 Cultural Relevance and Decolonizing Innovation

The folktale literacy kit and plant-geometry models illustrate how local culture can anchor modern science. By embedding storytelling and environmental observation into design, Bombeke aligns with UNESCO's (2023) call for culturally responsive STEAM education. These examples challenge the assumption that scientific reasoning is culturally neutral. Instead, they affirm that African knowledge systems and material culture are legitimate foundations for modern technology.

This decolonizing perspective is crucial in the post-aid era. When learning materials are locally conceived and fabricated, communities gain knowledge sovereignty (UNESCO, 2022). They no longer rely on imported kits that dictate content, language, or values. Bombeke's open-source ethos ensures that designs can be freely shared and adapted by schools, NGOs, or refugee communities without licensing restrictions-transforming the classroom from a site of consumption into a site of creation.

5.4 Institutional Growth and Technological Foresight

While the pilot focused on youth learning, the foundation has simultaneously been building institutional capacity to sustain and scale the model. In 2025 we began establishing a central office with enhanced technological infrastructure and collaborative space to host larger maker cohorts and community exhibitions. This facility anchors Bombeke's transition from project to permanent innovation hub.

The team has also partnered with a community-based nonprofit in Northern Uganda to conduct a Human-Centered Design (HCD) process for new educational materials in post-conflict districts. This partnership demonstrates adaptability: our methods can support other organizations seeking participatory, context-specific solutions.

Looking ahead, we are assessing the feasibility of hybrid (offline/online) tools versus IoT-based kits for remote and refugee schools. Using *Raspberry Pi* micro-controllers, we envision low-power learning servers that operate without constant internet access. This direction aligns with Uganda's *Digital Transformation Roadmap 2023* (Krishnan, 2023) and reinforces our commitment to sustainability under infrastructure constraints. Through such experimentation, Bombeke moves from classroom intervention to technological research platform, bridging education, design, and engineering.

5.5 *Ubuntu*, Self-Reliance, and Youth Readiness in the Post-Aid Era

Uganda's loss of major donor flows in 2024–2025 affected health, education, and refugee services, reminding us that dependence on foreign budgets is unsustainable. Against this backdrop, Bombeke embodies an indigenous philosophy of resilience rooted in both *Ubuntu* and *Ātmanirbhar Bharat* (self-reliance).

Ubuntu teaches empathy, solidarity, and mutual care, "I am because we are." *Ātmanirbhar* emphasizes local production and intellectual sovereignty. Merging the two yields, what we call shared self-reliance: a community's ability to meet its needs through collective creativity. In practice, Bombeke's learners design community benefit-making measuring cubes for parents, literacy tools for siblings, and science models for classmates. Each artifact reflects the moral economy of *Ubuntu* (serve others) and the pragmatic ethic of self-reliance (use what you have).

This synthesis does more than sustain the program; it cultivates the mindset required for Africa's next innovation wave. In every design sprint, children exercise cognitive patterns central to AI systems-recognizing patterns, abstracting variables, iterating models, and testing outputs. Yet they learn these skills through play, storytelling, and collaboration, grounded in cultural empathy. Thus, Bombeke prepares youth not just to use AI but to guide it ethically, ensuring that future intelligent systems serve collective good as well as personal advancement.

5.6 Comparison with Global Frameworks

Our experience resonates with international debates on *AI for Social Good* and *inclusive innovation (Holmes et al., 2022)*. Scholars such as Holmes et al. (2022) caution that global AI initiatives often reproduce inequality by ignoring local voices. Bombeke reverses this pattern: design originates from children's lived realities and scales outward through open sharing. In doing so, we contribute a Southern perspective to AI ethics-rooted in communal accountability rather than abstract regulation.

Furthermore, our model demonstrates that AI readiness can emerge without expensive technology. The habits of mind developed in Bombeke-critical thinking, empathy, and experimentation-constitute the human substrate on which ethical AI must stand. This insight supports UNESCO's (2023) recommendation that countries emphasize socio-emotional and ethical dimensions of AI literacy alongside technical skills.

5.7 A Model for Resilience and Policy Innovation

The lessons from Bombeke suggest new policy directions for education ministries and development partners. First, embedding youth participation within EdTech policies could institutionalize creativity at the classroom level. Second, funding should prioritize infrastructure that communities can own and maintain-solar energy, open-source software, and reusable materials. Third, partnerships between African and Asian innovation ecosystems can operationalize South-South learning, leveraging shared philosophies of *Ubuntu* and self-reliance.

Our experience also indicated that resilience was not only financial but psychological. By showing children that they can design meaningful technologies with limited means, we nurture confidence that persists beyond aid cycles. As one learner wrote in her reflection:

"Even if people stop helping, we can still continue because we know how to make." That sentence captures the essence of post-aid sustainability better than any policy statement.

5.8 Synthesis

Bombeke Foundation thus operates at three intertwined levels:

1. Educational – transforming how children learn through making and mentorship.
2. Technological – developing open, low-cost tools adaptable to diverse environments.
3. Philosophical – demonstrating that African values and Asian self-reliance principles together can redefine development for the twenty-first century.

In uniting these dimensions, the model contributes to a new vision of human-centered AI readiness grounded in compassion, competence, and community. It invites policymakers and educators to see youth not as future beneficiaries but as present co-innovators capable of shaping equitable digital futures.

6 Implications and Recommendations

6.1 Implications for Education Ministries and Policymakers

Our results demonstrate that meaningful STEM and AI-readiness education does not require expensive laboratories or constant donor funding. Instead, it depends on curricula that trust children as capable innovators. We therefore urge education ministries-particularly the Ministry of Education and Sports in Uganda-to embed youth-led, open-source design studios within national STEAM programs. Such integration would:

1. Institutionalize participation. Making participatory design part of classroom practice ensures that learners' voices influence learning materials and technology adoption.
2. Reform teacher preparation. Teacher-training colleges should include modules on design thinking, mentorship, and local resource innovation. This shift from instructor to facilitator aligns with the competency-based curriculum.
3. Promote multilingual and culturally grounded learning. Curriculum frameworks must recognize that technology can express culture-through folktales, crafts, and indigenous science analogies-rather than replace it.
4. Measure holistic outcomes. Policy indicators should value creativity, collaboration, and ethical reasoning alongside test scores.

If embedded nationally, the Bombeke model could complement the *Digital Transformation Roadmap 2023* by providing a scalable, community-owned approach to digital inclusion.

6.2 Implications for Funders and Development Partners

In a time of shrinking global aid, funders must rethink what sustainability means. Short-term projects that end when grants close no longer suffice. Investments should instead strengthen local innovation ecosystems that continue without constant external support (Aranda-Jan & Qasim, 2021).

Three priorities emerged:

1. Finance infrastructure, not dependency. Resources should target solar power, offline-first networks, and open-source tools that schools can maintain independently. Small, distributed labs yield longer-term impact than large donor-branded centers.
2. Support child-led and community-run labs. Funding criteria should reward projects that demonstrate genuine youth participation and intergenerational mentorship. Ownership builds accountability.
3. Encourage technological experimentation for offline contexts. Funders can back research into hybrid (offline/online) learning and IoT-enabled kits using Raspberry Pi,

allowing rural and refugee schools to access AI-era skills without continuous connectivity.

By investing in such resilient systems, partners contribute to post-aid sustainability rather than perpetuating aid dependence.

6.3 Implications for Research and Academic Institutions

Universities and research councils should view youth-led innovation as a legitimate domain of study and co-creation. Three directions emerge:

1. Longitudinal impact studies to track how early exposure to design-based learning influences career paths and community innovation.
2. Cross-continental comparative research linking African and Asian models of self-reliant innovation-operationalizing *Ubuntu* and *Ātmanirbhar* in empirical form.
3. AI literacy pedagogy studies to map how creative making fosters algorithmic reasoning and ethical awareness. Such evidence will inform both national policy and global education debates.

Bombeke's growing partnerships with Makerere University and Indian collaborators can serve as laboratories for this South-South research agenda.

6.4 Toward a New Development Compact

The future of equitable education lies in collaboration without dependency. As international aid recedes, Africa must cultivate home-grown institutions capable of sustaining creativity and ethics in technology. Bombeke Foundation offers a prototype for this shift: an initiative that begins small, draws strength from local culture, and scales through open knowledge rather than external capital.

At the same time, as a single-site case study with a relatively small sample size, these findings should be interpreted as exploratory and context-specific rather than fully generalizable. Future research should examine how similar models perform across different regions, including rural schools and refugee settlements, and with larger and more diverse participant groups. Comparative studies across multiple contexts will help validate the model's scalability and adaptability.

We therefore recommend that governments and regional bodies such as the African Union's CIEFFA and Smart Africa Alliance incorporate youth-led innovation labs into continental frameworks for digital-skills development. Such integration would not only build technical capacity but also embed Ubuntu's values of empathy and solidarity into Africa's technological future.

In summary, the implications of Bombeke's experience are both practical and philosophical: education systems must become makers of their own future. When youth design for their communities, and when policy enables that creativity, Africa moves from being a recipient of digital innovation to being its author. These implications extend beyond Uganda, offering lessons for youth-centered innovation in other low-resource contexts across the Global South.

7 Conclusion

The experience of the Bombeke Foundation demonstrates that youth empowerment in science and technology can emerge not from imported systems but from within communities themselves. Our three-month pilot in Kampala revealed that when children are given open tools, mentorship, and freedom to create, they do far more than learn-they begin to lead, building artifacts that connect school knowledge with daily life. Future studies will explore longitudinal outcomes and regional replication to assess scalability and long-term policy impact.

The outcomes confirm that open-source, youth-led design cultivates the very competencies needed in the age of AI: curiosity, abstraction, iteration, collaboration, and ethical awareness. Even without coding or robotics, learners practiced algorithmic reasoning by testing ideas, refining models, and predicting results. They learned that intelligence-human or artificial-grows through care, observation, and cooperation.

Equally significant, the program reaffirmed that technological learning is inseparable from cultural identity. By integrating *Ubuntu*'s compassion and self-reliance's determination, Bombeke offers a locally grounded response to the global post-aid reality. *Ubuntu* reminds us that progress must serve community well-being; self-reliance teaches us to use our own strengths to build that progress. Together, they define a moral framework for sustainable innovation, one where technology amplifies, rather than replaces, human connection.

The foundation's continuing evolution-from a single hub to a growing network with a central office, partnerships in Northern Uganda, and exploration of offline IoT tools-signals that community-driven innovation can scale responsibly. Each expansion builds local ownership, not dependence. In a world where external aid is uncertain, such models provide stability through capability.

Looking forward, the implications are clear. Uganda, and Africa more broadly, can cultivate AI-ready citizens not by importing curricula but by nurturing environments where children design, question, and imagine. Our responsibility is to sustain those environments-to make every school a space of invention and every child a potential innovator.

This is the future the Bombeke Foundation envisions: a continent where the spirit of *Ubuntu* fuels the practice of self-reliance, and where young Africans stand not at the periphery of the AI revolution but at its heart-guiding technology with wisdom, empathy, and courage.

Authors Note on AI Assistance

Editorial and language-structuring assistance for this paper was supported by AI-based tools under the direct supervision of the authors. All study design, data collection, interpretation, and analysis were conducted entirely by the authors of the Bombeke Foundation team. The paper's content reflects authentic field experiences, observations, and community-driven insights.

References

1. African Union Commission. (2020). *Digital transformation strategy for Africa (2020–2030)*. African Union. https://au.int/sites/default/files/documents/38507-doc-DTS_for_Africa_2020-2030_English.pdf
2. Aranda-Jan, C., & Qasim, Q. (2021). *Increasing access to technology for inclusion* (World Bank Group Gender Thematic Policy Notes Series: Evidence and Practice Note). World Bank Group. https://documents1.worldbank.org/curated/en/099631003072338051/pdf/IDU0116c98a904ebc04dc30a47a0495a00553bae.pdf
3. Bevan, B., Gutwill, J. P., Petrich, M., & Wilkinson, K. (2015). Learning through STEM-rich tinkering: Findings from a jointly negotiated research project taken up in practice. *Science Education, 99*(1), 98–120. https://doi.org/10.1002/sce.21151
4. Charmaz, K. (2014). *Constructing Grounded Theory* (2nd ed.). SAGE Publications.
5. Druin, A. (2002). The role of children in the design of new technology. *Behaviour & Information Technology,* 21(1), 1–25. https://doi.org/10.1080/01449290110108659
6. Ehn, P. (1988). *Work-oriented design of computer artifacts*. Arbetslivscentrum. https://www.academia.edu/111106915/Work_oriented_design_of_computer_artifacts
7. Fraser, S. (2025, March 20). *Consequences and implications for the international development assistance sector from the closure of USAID*. Global Policy Journal. https://www.globalpolicyjournal.com/blog/20/03/2025/consequences-and-implications-international-development-assistance-sector-closure
8. Holmes, W., Bialik, M., & Fadel, C. (2022). *Artificial intelligence in education: Promises and implications for teaching and learning*. Center for Curriculum Redesign. https://curriculumredesign.org/wp-content/uploads/AIED-Book-Excerpt-CCR.pdf
9. Human Rights Watch. (2024). *Impact of global aid withdrawal on refugee services in Uganda*. HRW Press. https://www.hrw.org/world-report/2024/country-chapters/uganda
10. Krishnan, R. V. (2023). *Disclosable version of the ISR – Uganda Digital Acceleration Project – GovNet – P171305 – Sequence No: 04 (English)*. World Bank Group. http://documents.worldbank.org/curated/en/099060623211537269
11. Liyanagunawardena, T., Williams, S., & Adams, A. (2013). The impact and reach of MOOCs: A developing countries' perspective. *eLearning Papers, 33*, 1–8. https://www.academia.edu/3506625
12. Martinez, S. L., & Stager, G. (2013). *Invent to learn: Making, tinkering, and engineering in the classroom*. Constructing Modern Knowledge Press. https://constructingmodernknowledge.com/read-this-get-a-free-book/
13. Ministry of Information, Communications Technology & National Guidance. (2025). Strategic plan FY 2025/2026–2029/2030. Government of Uganda. https://ict.go.ug/site/documents/ict-strategic-plan-202526-202930.pdf
14. Papert, S. (1980). *Mindstorms: Children, Computers, and Powerful Ideas.* Basic Books.
15. Pearce, J. M. (2019). *Open-source lab: How to build your own hardware and reduce research costs*. Elsevier. https://shop.elsevier.com/books/open-source-lab/pearce/978-0-12-410462-4
16. Uganda Bureau of Statistics. (2023). Statistical abstract 2023. UBOS. https://www.ubos.org/2023-statistical-abstract/
17. UNESCO Institute for Lifelong Learning. (2022). *Leveraging innovative technology in literacy and education programmes for refugees, migrants, and internally displaced persons*. UNESCO. https://files.eric.ed.gov/fulltext/ED627597.pdf
18. UNESCO. (2023a). *AI competency framework for students*. UNESCO. https://www.unesco.org/en/articles/ai-competency-framework-students

19. UNICEF. (2013). *Ethical research involving children: Guidelines and checklists*. UNICEF. https://www.unicef.org/innocenti/media/9181/file/Ethical-Research-Involving-Children-compendium-2013-EN.pdf.pdf
20. UNESCO. (2023b). *Global education monitoring report 2023: Technology in education-A tool on whose terms?* UNESCO. https://unesdoc.unesco.org/ark:/48223/pf0000385723
21. UNICEF. (2021). *Guidance on child and adolescent participation in planning, design, and monitoring: European Child Guarantee Phase III*. UNICEF. https://www.unicef.org/eca/media/19426/file/ChildandAdolescentParticipationintheCG
22. Yin, R. K. (2018). *Case Study Research and Applications: Design and Methods* (6th ed.). SAGE Publications.