

Leveraging AI and STEAM for Resilient and Sustainable Economic Development Through Open Education: A Case for Eswatini

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Theme: Innovative Open Education: Fostering Resilient Societies for Sustainable Economic Development

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Abstract

This paper explores how integrating Artificial Intelligence (AI) and Science, Technology, Engineering, Arts, and Mathematics (STEAM) into open education, particularly within Technical and Vocational Education and Training (TVET), can foster resilient and sustainable economic development in the Kingdom of Eswatini. The study critically examines Eswatini's national transformation agenda, focusing on the TVET Policy 2022–2027, the National Development Plan 2023/24–2027/28, and the Education Sector Strategic Plan (ESSP) 2022–2034, which aim to address pressing socio-economic challenges: youth unemployment (49–56%), poverty (59% in 2017), and inequality (Gini coefficient ~0.55). Rooted in the African philosophy of Ubuntu, which emphasizes communal interdependence and mutual care, the paper advocates for inclusive, multi-sectoral strategies to ensure equitable access to education. Through a qualitative methodology combining policy analysis, literature review, and comparative case studies from Kenya, Rwanda, India, and Singapore, the study identifies best practices for AI-enhanced STEAM education within an open learning ecosystem. Tables and matrices summarize frameworks, while findings highlight the potential of technology-driven education to reduce unemployment, foster innovation, and promote social cohesion. The paper concludes with comprehensive policy recommendations and practical implications for educators, policymakers, and stakeholders, emphasizing collaboration across government, industry, and communities to achieve inclusive economic transformation.

1.0 Introduction

Eswatini, a small landlocked nation in Southern Africa with a population of approximately 1.2 million, is classified as a lower-middle-income country facing significant socio-economic challenges. Youth unemployment rates range from 49% to 56%, with over 53% of young people not in education, employment, or training (NEET) as of 2023. Poverty affects nearly 59% of the population (2017 data), and income inequality is stark, with a Gini coefficient of approximately 0.55. These challenges have been exacerbated by global disruptions, notably the COVID-19 pandemic, which exposed vulnerabilities in education delivery and underscored the need for resilient, accessible systems. During the pandemic, Eswatini relied on open and distance learning (ODL) modalities—radio, television, and printed materials—to maintain educational continuity, particularly for rural students with limited internet access. This experience highlighted the transformative potential of open education to ensure inclusivity and continuity during crises.

The government of Eswatini has identified education, particularly Technical and Vocational Education and Training (TVET) and STEAM disciplines, as critical drivers of economic diversification and innovation. The TVET Policy 2022–2027 outlines a comprehensive vision to overhaul the TVET system through five key objectives: improving governance, securing sustainable funding, enhancing graduate quality, aligning

programmes with labor market needs, and expanding access for youth and adults. These goals align with broader national strategies, such as the National Development Plan 2023/24–2027/28, which prioritizes human capital development and job creation in high-growth sectors like agriculture, manufacturing, technology, and tourism. Central to Eswatini’s approach is the African philosophy of Ubuntu, meaning “I am because we are,” which emphasizes communal interdependence, mutual care, and collective responsibility. By embedding Ubuntu principles, Eswatini aims to foster an inclusive education system that ensures no one is left behind, aligning with the PCF11 theme of building resilient societies capable of withstanding economic and social shocks.

This paper argues that leveraging AI and STEAM within an open education framework, designed in partnership with industry, communities, and international stakeholders, can transform Eswatini’s economic trajectory. By equipping learners with 21st-century skills—such as coding, data analysis, critical thinking, and problem-solving—open TVET/STEAM programmes can reduce unemployment, mitigate inequality, and promote sustainable development. The study bridges theory and practice, offering actionable insights for policymakers, educators, and communities to create a future-ready education system rooted in Eswatini’s cultural values of Ubuntu.

2.0 Theoretical Framework

The theoretical foundation of this study integrates three interconnected concepts: open education, Ubuntu philosophy, and AI-driven STEAM innovation. Open education, encompassing open distance learning (ODL) and open educational resources (OER), is built on principles of accessibility, flexibility, and equity, aiming to democratize learning opportunities for diverse populations, including rural and marginalized communities. ODL enables flexible delivery through online platforms, radio, and print, while OER provides free, adaptable educational materials, reducing barriers to quality education.

Ubuntu, a Southern African philosophy encapsulated by the phrase “I am because we are,” emphasizes communal interdependence, empathy, and shared progress. As Ngubane-Mokiwa (2016) argues, an Ubuntu-informed pedagogy prioritizes learner-centeredness, kindness, and cooperation among stakeholders—students, educators, communities, and policymakers. In the context of Eswatini, Ubuntu ensures that educational innovations are inclusive, addressing the needs of marginalized groups such as rural learners, women, youth, and people with disabilities. This philosophy aligns with open education’s equity goals, fostering a sense of collective responsibility to ensure all learners succeed.

AI and STEAM serve as technological and disciplinary pillars to accelerate skills development. AI can enhance learning through adaptive platforms, personalized feedback, virtual simulations, and data-driven insights, while STEAM disciplines cultivate critical thinking, creativity, and innovation essential for the Fourth Industrial Revolution (4IR). However, technological advancements must be guided by social values to avoid exacerbating inequalities. By weaving together open education, Ubuntu, and AI/STEAM, this framework posits that Eswatini’s education system can achieve both technical proficiency and social cohesion, creating a supportive, inclusive learning ecosystem that empowers all learners to contribute to economic and societal development.

3.0 Methodology

This research employs a qualitative, exploratory approach, combining three methods: policy analysis, literature review, and comparative case studies. The policy analysis examined key Eswatini documents, including the TVET Policy 2022–2027, the Education Sector Strategic Plan (ESSP) 2022–2034, the Multi-Year Action Plan (MYAP) 2022/23–2024/25, the Gwamile VOCTIM Final Report, and recent ministerial speeches on education reform. Content analysis techniques were used to identify recurring themes—such

as “AI,” “STEAM,” “inclusion,” “industry partnership,” and “skills development”—to assess policy priorities, gaps, and implementation strategies.

The literature review surveyed scholarly and institutional sources, including publications from UNESCO, the Commonwealth of Learning (COL), the African Union (AU), and the Southern African Development Community (SADC). These sources contextualized Eswatini’s efforts within global and regional trends, such as the push for competency-based education, digital transformation, and 4IR skillsets (e.g., coding, robotics, data science). The review also explored the role of AI in TVET and open education, drawing on case studies and best practices to inform recommendations.

Comparative case studies analyzed four countries—Kenya, Rwanda, India, and Singapore—selected for their innovative approaches to integrating AI and STEAM into education. Kenya’s AI National Skilling Initiative, Rwanda’s STEAM Centre of Excellence, India’s National Education Policy (NEP) 2020, and Singapore’s SkillsFuture program provided insights into scalable models, flagship institutions, early vocational exposure, and lifelong learning ecosystems. Data were gathered from policy documents, international reports, and press releases, with a comparative matrix summarizing key initiatives, strengths, and lessons for Eswatini.

Generative AI tools, such as ChatGPT, were ethically integrated into the research process for literature discovery, information synthesis, and drafting initial sections. All AI-generated content was rigorously reviewed and edited by human researchers to ensure accuracy, coherence, and originality, aligning with ethical research standards. This use of AI reflects the paper’s theme, demonstrating how technology can enhance educational workflows when guided by human expertise. The methodology triangulated data from policy documents, statistical databases (e.g., World Bank, UNESCO, ILO), and expert commentary to ensure rigor. Limitations include reliance on potentially optimistic policy reports and the challenge of applying lessons from diverse contexts to Eswatini’s unique socio-economic and cultural environment. Despite these constraints, the methodology provides a robust foundation for the analysis and recommendations.

4.0 Literature review

4.1 Context: Eswatini’s TVET and STEAM Transformation Agenda

Eswatini’s TVET Policy 2022–2027 is a cornerstone of its education reform agenda, addressing systemic challenges such as fragmented governance, inadequate funding, outdated curricula, and societal stigma around vocational education. The policy’s five objectives—improving governance, securing sustainable funding, enhancing graduate quality, aligning programmes with labor market needs, and expanding access—aim to create a robust, relevant TVET system. These goals are supported by the Education Sector Strategic Plan (ESSP) 2022–2034 and the Multi-Year Action Plan (MYAP) 2022/23–2024/25, which outline specific activities, timelines, and budgets. For example, the MYAP prioritizes competency-based curricula in key sectors like agriculture, manufacturing, and ICT, alongside infrastructure upgrades at institutions like Gwamile VOCTIM and the Eswatini College of Technology (ECOT). ECOT is slated to become a University of Applied Science and Technology, offering advanced vocational qualifications. Other initiatives include establishing a TVET Development Fund, integrating TVET institutions into the Education Management Information System (EMIS), and launching advocacy campaigns to improve TVET’s societal perception. Part-time and evening programmes further enhance accessibility for working adults and non-traditional learners.

4.2 Challenges and Gaps

Despite policy progress, Eswatini faces significant challenges. The unemployment crisis, with youth unemployment at ~50% and a NEET rate of 53% (2023), reflects a disconnect between education and employment. Each year, approximately 25,000 young people enter the labor market, but only ~1,000 formal jobs are created, underscoring the need for entrepreneurship and self-employment training. However, older TVET curricula lack robust entrepreneurship components, limiting graduates' ability to create their own opportunities. The MYAP addresses this by promoting on-farm production and value chain skills, but implementation remains nascent.

Infrastructure and digital access pose further challenges. AI and STEAM integration requires reliable electricity, internet, and equipment, yet rural schools often lack basic resources like computer labs. The 2020 shift to ODL during COVID-19 revealed digital divides, with some students unable to access radio or TV lessons due to economic pressures or lack of devices. Urban-rural disparities exacerbate inequities, necessitating investments in connectivity (e.g., through a Universal Service Fund) and low-tech OER for offline learners. Cultural attitudes, including stigma around TVET and resistance to AI among some educators, also hinder progress. Addressing these gaps requires innovative financing, stakeholder engagement, and a commitment to inclusivity rooted in Ubuntu.

4.3 Comparative Analysis: Regional and Global Best Practices

Kenya

In late 2024, Kenya launched the AI National Skilling Initiative, targeting 100,000 TVET students and instructors in partnership with Microsoft through the Konza Technopolis project. The program provides training in machine learning, data science, and AI app development across 16 pilot digital hubs, with plans to expand to 25 more by 2026. Kenya's Competency-Based Curriculum (CBC), implemented since 2017, emphasizes practical skills and digital literacy from early grades, with some schools adopting AI-powered platforms like adaptive learning tools. A 2023 assessment highlighted a key challenge: teacher training has not kept pace with AI integration, limiting scalability. Nevertheless, Kenya's public-private partnership model, leveraging "Jitume" ICT hubs, offers a scalable approach for Eswatini to develop AI training infrastructure through collaboration with tech firms and donors.

Rwanda

Rwanda has emerged as a regional leader in leveraging technology for development, particularly through its focus on STEAM. The African STEAM Centre of Excellence (ASTEAM CoE) in Kigali, supported by the UN Economic Commission for Africa, enhances curricula, trains teachers, and exposes students to technologies like robotics, AI, and 3D printing. The Rwanda Coding Academy and secondary-level programming courses promote digital skills, while initiatives like girls' mentoring boot camps, partnered with organizations like FAWE, ensure inclusivity. Rwanda's National Strategy for Transformation aligns education with ICT and human capital development, demonstrating strong political will. Eswatini can emulate Rwanda's flagship programs, centralized coordination, and gender equity initiatives to galvanize STEAM education and attract international support.

India

India's National Education Policy (NEP) 2020 represents a transformative approach to education, mainstreaming vocational training and AI literacy from Grade 6 to destigmatize TVET and enhance employability. The policy mandates vocational exposure for all students, integrating subjects like coding

and AI into curricula. Platforms like Diksha (Digital Infrastructure for Knowledge Sharing) and the AI For All program deliver digital content and train students and teachers in AI basics. ODL initiatives target school dropouts, ensuring inclusivity. India’s scale is vastly different, but its focus on early vocational exposure and low-cost AI integration (e.g., coding clubs in rural schools) offers practical lessons for Eswatini, which can implement similar programmes on a smaller scale using low-cost devices and project-based learning.

Singapore

Singapore’s SkillsFuture initiative is a global benchmark for lifelong learning, using AI to provide personalized training recommendations based on individuals’ job histories and market trends. This ensures workforce adaptability in high-demand sectors like fintech and healthcare. TVET programmes in Singapore leverage AI-driven simulations and virtual reality (VR) for immersive training in fields like aviation and nursing, allowing safe, cost-effective practice. Singapore’s ecosystem integrates initial education, TVET, and continuous learning, aligning skills with economic needs in near real-time. Eswatini can adopt a simplified AI-driven career guidance system to address skill mismatches and explore VR simulations for TVET, even if initially through donor-funded pilots. Table 1 below presents the summary of the comparative analysis of the four countries.

Table 1: Comparative Matrix of AI and STEAM Initiatives

Country	Key Initiative	Strengths	Relevance to Eswatini
Kenya	AI Skilling Initiative	Public-private partnerships, scalability	Model for AI training hubs
Rwanda	STEAM Centre of Excellence, Coding Academy	Centralized vision, gender inclusivity	Flagship programs, girls’ inclusion
India	NEP 2020, AI for All	Early vocational exposure, ODL	Low-cost AI and coding integration
Singapore	SkillsFuture, AI-driven recommendations	Lifelong learning, adaptability	AI career guidance, VR simulations

4.4 SADC and African Initiatives

Within the SADC region, Namibia’s TVET reforms incorporate 4IR technologies like augmented reality (AR) and VR, supported by industry internships and a task force to align training with market needs. South Africa has introduced coding and robotics in school curricula and expanded digital skills in TVET colleges, though quality and throughput challenges persist. The African Union’s Continental Education Strategy for Africa (CESA) and Digital Transformation Strategy emphasize ODL and digital skills across member states. Eswatini can leverage regional collaboration, such as Botswana’s ODL programmes or Mauritius’s ICT initiatives, to share resources, content, and expertise, reducing costs and enhancing capacity.

5.0 Findings and Discussion

The analysis reveals five strategic imperatives for Eswatini to leverage AI and STEAM through open education for resilient and sustainable economic development:

- 5.1 Governance and Multi-Sector Collaboration:** Effective transformation requires breaking silos and fostering collaboration among government ministries (Education, Labor, ICT, Economic Planning), industry, educators, and communities. A high-level Skills Development Council, guided by Ubuntu’s emphasis on collective responsibility, can align AI/STEAM initiatives with labor market needs. Kenya’s partnership with Microsoft and Rwanda’s collaboration with the UN demonstrate the value of resource pooling. Eswatini’s World Bank-supported Employment and Youth Empowerment Opportunity Project (EYEOP) can be integrated with TVET curricula to maximize impact. A national open education platform, hosted by the Eswatini Higher Education Council, could centralize ODL resources, AI tools, and OER, supported by regional bodies like SADC or COL. Community representatives in governance structures ensure inclusivity, reflecting Ubuntu values.
- 5.2 Curriculum and Pedagogy Transformation:** Modernizing TVET curricula to include AI, digital literacy, and competency-based learning is critical. AI can enhance content by introducing topics like data science and machine learning, even in non-IT trades, to build awareness. Delivery can leverage AI-driven tools, such as adaptive learning platforms (e.g., India’s Diksha) and VR simulations (e.g., Singapore’s healthcare training). Blended learning, modular courses, and recognition of prior learning ensure flexibility, aligning with Ubuntu’s inclusivity. Teacher training in project-based learning, flipped classrooms, and digital tools is essential to support this shift. For example, a TVET carpentry course could include a module on using AI to optimize material use, blending technical and digital skills.
- 5.3 Infrastructure and Resource Mobilization:** Addressing digital divides requires significant investment in connectivity, equipment, and training. The proposed TVET Fund, sourced from government budgets, industry levies, and donor contributions, can support ICT infrastructure upgrades, such as computer labs and internet access in schools and TVET centers. Public-private partnerships with telecom companies (e.g., providing data bundles or zero-rated educational websites) and tech firms (e.g., donating cloud services for AI labs) can enhance access. Off-grid solutions, like solar-powered ICT labs used in rural African schools, are viable for Eswatini’s remote areas. A national ODL platform with offline access (via SD cards or school servers) can broaden reach, ensuring inclusivity for learners without internet access.
- 5.4 Cultural Change and Inclusion (Ubuntu Lens):** Changing societal perceptions about TVET, gender roles in STEAM, and AI adoption is crucial. Community dialogues, guided by Ubuntu’s emphasis on mutual care, can build support and reduce resistance. Some Eswatini teachers fear AI may replace them, necessitating training that frames AI as an empowering tool for personalized learning and workload reduction (e.g., automating grading). Gender equity initiatives, such as scholarships for women in engineering, girls’ coding clubs, and mentorship programs, can increase female participation in STEAM, drawing on Rwanda’s success. Accessibility tools, like speech-to-text for learners with disabilities, ensure inclusivity. Highlighting local role models—e.g., Eswatini women in tech—can inspire participation and align with Ubuntu’s community focus.
- 5.5 Sustainability and Scaling:** Successful pilots, such as TaiwanICDF projects at VOCTIM/ECOT, must be institutionalized through national standards and robust monitoring. Annual tracer studies tracking TVET graduate outcomes (e.g., employment rates, entrepreneurial ventures) can inform policy adjustments. A flexible national qualifications framework incorporating micro-credentials (e.g., digital badges for AI skills) supports lifelong learning, as seen in Singapore. AI analytics can continuously refine programmes by analyzing labor market trends and learner performance, ensuring adaptability. Eswatini can contribute case studies to global forums like UNESCO or COL, raising its profile and attracting further support.

6.0 Recommendations

The study recommends the following for practice and policy:

6.1 Establish an Open STEAM & Skills Task Force: Create a multi-sector task force under the Ministry of Education and Training, including Economic Planning, ICT, industry (e.g., agribusiness, tech firms), and community representatives, to oversee AI/STEAM integration. A technical working group can pilot initiatives like AI curricula in teacher training and STEAM clubs in schools, following Kenya’s collaborative model. The task force should ensure alignment with national development goals and Ubuntu principles.

6.2 Invest in Educator Capacity and Digital Pedagogy: Implement large-scale training programmes for teachers, TVET instructors, and education managers on AI, STEAM, and digital pedagogy. Training should cover technical skills (e.g., using learning management systems) and innovative pedagogies (e.g., project-based learning, competency-based assessment). International partnerships with organizations like COL or India’s Diksha platform can provide online courses and exchanges. Incentives, such as certifications or salary increments, can encourage participation. Training should address teacher concerns about AI, framing it as an assistive tool to enhance teaching.

6.3 Develop a National ODL Platform: Build a robust ODL platform hosting OER, AI-driven chatbots, and educational content in English and siSwati, accessible online and offline (via SD cards or school servers). Partner with broadcasters to deliver radio and TV programs, such as “Practical Science at Home,” to spark youth interest. The platform can include interactive modules, like virtual labs for STEAM subjects, ensuring inclusivity for rural and low-income learners.

6.4 Integrate AI and Coding in Curricula: Introduce computational thinking, coding, and AI ethics in secondary and upper primary curricula, using tools like Scratch or Python. For example, a Grade 7 mathematics class could incorporate coding exercises to solve equations, while TVET programmes could offer electives on AI applications in agriculture or finance. National STEAM competitions and hackathons, supported by the Ministry of ICT and tech hubs, can motivate students and identify talent, as seen in Rwanda.

6.5 Strengthen Industry Linkages and Entrepreneurship: Establish Advisory Boards for TVET institutes with local business leaders to co-design curricula and assessments. Create Innovation Labs, such as an agro-technology lab at an agricultural college or an AI incubator at VOCTIM, to develop local solutions (e.g., AI for Swazi crafts marketing). Embed entrepreneurship training in all TVET programs, covering business planning, financial literacy, and access to microfinance or startup grants through initiatives like EYEOP, empowering graduates as job creators.

6.6 Implement Open Monitoring and Research: Develop a robust monitoring and evaluation (M&E) framework to track indicators like TVET enrollment (by gender), completion rates, and graduate employment outcomes. Publish annual “Skills and Employment” reports using open data, similar to the World Economic Forum’s Future of Jobs report. Encourage local research at the University of Eswatini to pilot AI in education, contributing to global forums like UNESCO or COL to attract support and share insights.

6.7 Ensure Ethical and Inclusive AI Use: Develop AI ethics guidelines based on UNESCO’s framework, prioritizing data privacy, transparency, and inclusivity. AI systems, like career guidance tools, should avoid biases (e.g., gender stereotypes) and provide outputs in text, voice, and local languages to accommodate diverse learners. Community engagement and transparent communication will build trust in AI among educators and the public.

7.0 Implications for Practitioners

7.1 Continuous Professional Development: Teachers and TVET instructors must engage in ongoing training in AI, STEAM, and digital tools through workshops, online courses, and professional learning communities. School leaders should allocate time and funding, ensuring educators are equipped to deliver modern curricula.

- 7.2 Learner-Centered Pedagogy:** Shift from rote teaching to interactive methods like project-based learning and flipped classrooms. For example, a TVET instructor could assign OER videos for home study, using class time for hands-on coding or mechanics projects. OER, such as Khan Academy modules or open textbooks, can enrich curricula and reduce costs.
- 7.3 Community Engagement:** Educators should organize STEAM fairs, tech literacy classes, and community projects, aligning with Ubuntu’s focus on collective well-being. For instance, students could showcase solar-powered devices at village events, fostering community support for education reforms.
- 7.4 Soft Skills and Ethics:** Emphasize 21st-century skills—critical thinking, collaboration, creativity, and communication—through group projects and discussions on AI ethics. These skills prepare students for adaptable careers and resonate with Ubuntu’s values of empathy and cooperation.
- 7.5 Assessment Reforms:** Adopt practical assessments, such as portfolios, capstone projects, and competency demonstrations, to evaluate skills authentically. For example, a TVET student might be assessed on designing a simple AI-powered irrigation system, integrating technical and digital competencies.
- 7.6 Facilitator Role:** As AI tools (e.g., tutoring apps) support learning, teachers should focus on mentorship, guiding students to use technology critically and creatively. This synergy enhances learning outcomes while preserving the human touch in education.

8.0 Conclusion

Eswatini’s pursuit of resilient and sustainable economic development through innovative open education is both urgent and achievable. The TVET Policy 2022–2027, ESSP, and National Development Plan provide a strong foundation, while Ubuntu ensures inclusivity and community-driven progress. Comparative insights from Kenya, Rwanda, India, and Singapore highlight the power of public-private partnerships, early STEAM exposure, flagship programs, and AI-driven lifelong learning. By addressing local challenges—connectivity, teacher readiness, and cultural attitudes—through targeted investments, stakeholder engagement, and adaptive implementation, Eswatini can create an open, technology-enhanced education system. This system will empower youth, reduce inequalities, and foster innovation, aligning with the proverb, “If you want to go far, go together.” Through collective action rooted in Ubuntu, Eswatini can build a prosperous, resilient future where all citizens thrive through education and innovation.

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