

Developing a Web-Based Learning System for TVET: Enhancing Digital and Entrepreneurial Skills for African Youth

Ibrahim Mohammed, Ibrahim Umar Kontagora, Aishatu Aliyu Mohammed, Peter Bake, Hakilatu Yahuza, Abdulsamad Sadiq, and Abubakar Yusuf

Department of Computer Science, Niger State Polytechnic Zungeru, Niger State, Nigeria.
Corresponding Author Email: ibmkhaleel@gmail.com

ABSTRACT: *The emergence of Industry 4.0 necessitates a paradigm shift in Technical and Vocational Education and Training (TVET), particularly in sub-Saharan Africa, where conventional programmes often fail to meet the evolving demands of the digital economy. Traditional approaches remain limited in accessibility, scalability, and alignment with industry competencies, leaving a persistent gap between education and employability. This study introduces and evaluates a web-based learning system designed to deliver practical, industry-driven training in web development, digital entrepreneurship, and information and communication technology (ICT). The system integrates interactive learning modules, real-time coding exercises, and entrepreneurial project development to ensure experiential and market-relevant training. Built with adaptive offline capabilities, the platform caters to learners in remote areas with limited internet access, thus addressing the infrastructural constraints that hinder traditional TVET delivery. A six-month pilot study was conducted with 150 participants from Nigeria and Kenya, utilizing a mixed-methods research approach. Pre- and post-assessment data were analysed using the LeetCode for Africa benchmark to measure skill acquisition, while user engagement metrics and industry adoption analyses were employed to assess learning outcomes and relevance to the labour market. Results revealed a 72.4% average improvement in technical skill proficiency, accompanied by an 83% completion rate for entrepreneurial modules. Notably, 41% of participants successfully launched micro-businesses within three months of programme completion, indicating strong entrepreneurial translation of skills. Industry validation further confirmed that 78% of graduate projects achieved a 'job-ready' rating based on a four-dimensional employability rubric encompassing technical accuracy, innovation, scalability, and cultural relevance. Qualitative insights reinforced these findings, highlighting the platform's contextual adaptability and mentorship-based learning. As one participant from rural Kenya stated, "The offline mode saved me when my village had no internet for weeks," while another from Nigeria remarked, "Building a fintech prototype with a Lagos mentor gave me real startup experience." The findings underscore the potential of technology-driven TVET to bridge industry-skills gaps, foster entrepreneurial ecosystems, and empower African youth to thrive in the global digital economy. The study offers a scalable model for future skills development, providing evidence-based insights for policymakers, educational institutions, and industry stakeholders seeking to reimagine TVET in the era of Industry 4.0.*

Keywords: *TVET, digital skills, web-based learning, entrepreneurship, youth empowerment*

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INTRODUCTION

The global economy is undergoing a profound transformation driven by the forces of Industry 4.0, characterized by the convergence of advanced digital technologies, automation, artificial intelligence (AI), and interconnected systems that are reshaping the nature of work and the skills required to thrive within it (Schwab, 2017). This technological revolution not only disrupts traditional employment structures but also introduces new economic opportunities, necessitating a workforce that is agile, digitally competent, and entrepreneurial (UNESCO, 2021). While these shifts are universal, their implications for Africa are particularly significant, given the continent's unique demographic profile, socio-economic realities, and aspirations for inclusive industrialization as outlined in Agenda 2063 of the African Union (AU, 2015).

Africa is home to the world's youngest population, with over 60% of its citizens under the age of 25 (African Development Bank AfDB, 2023). This demographic dividend presents a potential competitive advantage, offering a burgeoning labour force capable of fuelling innovation and economic growth. However, it also poses a critical challenge: youth unemployment remains persistently high, with estimates suggesting that nearly 40% of young people are either unemployed or underemployed (ILO, 2022). The mismatch between educational outcomes and labour market demands is a primary factor underpinning this challenge. Many graduates lack the technical, digital, and entrepreneurial competencies required to participate meaningfully in a rapidly evolving knowledge economy (World Bank, 2023). Thus, equipping young people with future-ready skills is not only a developmental imperative but also a socio-economic necessity.

Technical and Vocational Education and Training (TVET) has long been recognized as a strategic vehicle for fostering employability, promoting industrial competitiveness, and enhancing economic resilience (UNESCO-UNEVOC, 2020). TVET encompasses a broad range of learning experiences formal, non-formal, and informal that are designed to develop skills and knowledge relevant to specific occupations, industries, or entrepreneurial ventures. In Africa, TVET has gained renewed policy attention as governments and development agencies seek scalable and sustainable solutions to address the skills deficit (African Union, 2020). However, despite its potential, conventional TVET models face a series of structural and operational limitations that compromise their effectiveness. Curricula are often outdated, with many programs failing to integrate emerging digital competencies or align with the evolving needs of industry (World Bank, 2023). Technological trends advance rapidly, yet TVET curricula may lag by five to seven years, resulting in graduates who are inadequately prepared for contemporary job roles (ILO, 2022). Accessibility remains a persistent challenge, with approximately 60% of rural learners lacking stable internet

connectivity (GSMA, 2024), which limits participation in digital learning environments and exacerbates socio-economic inequities in education. Moreover, entrepreneurial training is significantly underrepresented in existing TVET frameworks, with only 12% of programs incorporating modules that cultivate innovation, startup incubation, and self-employment pathways (AfDB, 2022). This omission is particularly problematic in contexts where formal job creation is insufficient to absorb new entrants into the labour force, making entrepreneurship a critical avenue for employment generation and economic dynamism.

Digital innovation emerges as a transformative enabler capable of addressing structural gaps in African TVET systems. Web-based learning platforms offer unique opportunities to democratize access, modernize content, and foster interactive, learner-centred experiences that are responsive to market demands (Kigotho & Samoff, 2022). By leveraging mobile technology and cloud-based solutions, such platforms can transcend geographic, infrastructural, and logistical barriers that have historically limited the reach of conventional training programmes. Moreover, the integration of entrepreneurial learning environments within digital platforms provides a scalable means to cultivate startup culture and innovation capabilities among African youth, bridging the gap between skill acquisition and practical application.

This paper proposes an innovative web-based TVET model that is contextually tailored to African realities, featuring three key advancements. Firstly, a hybrid online-offline functionality ensures uninterrupted learning for participants in low-connectivity areas through downloadable course packs and automated data synchronization upon reconnection. Secondly, an industry-embedded curriculum, co-developed with leading African technology employers such as Andela and Flutterwave, guarantees alignment with labour market requirements and emerging sectoral trends. Finally, an entrepreneurial sandbox environment provides learners with the opportunity to develop and prototype real startup ideas under the mentorship of African tech founders, promoting applied learning and innovation-driven mindsets.

The rationale for this intervention is informed by the scale and urgency of Africa's digital skills deficit. The African Union estimates that the continent will require at least 650 million digitally skilled workers by 2030 to support its transition into a knowledge-driven economy (AU, 2021). Yet, less than 20% of TVET graduates currently meet the competency thresholds required by technology employers (Andela, 2023), signalling a profound gap between training outcomes and labour market demands. Moreover, existing global learning platforms, such as Coursera and Udemy, while valuable, often lack contextual relevance for African learners, relying heavily on case studies, pedagogies, and languages that do not reflect regional economic realities or cultural diversity (Kigotho & Samoff, 2022).

Three critical gaps emerge from this analysis: content relevance, access inequality, and entrepreneurial orientation. TVET curricula often remain static, with limited incorporation of cutting-edge technological skills and entrepreneurial competencies (World Bank, 2023). Infrastructure and connectivity barriers exclude significant portions of the population, especially in rural and underserved communities (GSMA, 2024). Existing programs fail to cultivate the skills and innovation mindsets necessary for fostering self-employment and local enterprise development (AfDB, 2022). The proposed web-based TVET platform addresses these gaps by combining curriculum modernization, digital inclusion strategies, and embedded entrepreneurial training. Beyond technical skill-building, the model seeks to position learners as active participants in Africa's digital transformation capable not only of entering the workforce but also of creating economic opportunities that contribute to inclusive growth and sustainable development. This study contributes to the discourse on skills development in Africa by advancing a novel framework that integrates technological innovation, contextual curriculum design, and entrepreneurial capacity building into a unified TVET model. In doing so, it extends existing scholarship on digital learning and workforce readiness (UNESCO, 2021; ILO, 2022), offering empirical and theoretical insights into how web-based systems can mitigate structural limitations of conventional training programs. Furthermore, the paper provides a foundation for policy formulation, institutional reform, and private-sector collaboration aimed at equipping African youth with the capabilities necessary to thrive in a digital and innovation-driven economy.

LITERATURE REVIEW

The Role of TVET in Digital and Entrepreneurial Skill Development

Technical and Vocational Education and Training (TVET) is widely recognized as a catalyst for youth empowerment, equipping learners with practical competencies essential for employment and entrepreneurial ventures (McGrath & Powell, 2016). Nevertheless, research indicates that many TVET programmes in Africa remain inadequately integrated with information and communication technologies (ICT), limiting their potential to prepare learners for digital career pathways (Keneth, 2018). The World Bank (2020) reports that only 30% of TVET institutions in sub-Saharan Africa currently offer courses that develop digital skills. Empirical studies suggest that web-based TVET platforms significantly enhance learning outcomes and improve job readiness, particularly in resource-constrained regions (Oyelere et al., 2020). Frameworks such as TVET 4.0 in Ghana demonstrate how digital skills integration can strengthen technical universities and provide a replicable model across Africa (Asare & Osei, 2023). However, persistent challenges

including unreliable internet connectivity and infrastructural gaps continue to undermine their impact, highlighting the necessity for innovative, context-specific solutions. Although global e-learning platforms such as ALISON provide digital training modules, they often fail to address the specific needs of African learners, including content localization, offline accessibility, and industry validation. Table 1 summarizes the gaps in existing solutions relative to the proposed system.

Table 1. Gap analysis of existing solutions.

Feature	Global Platforms	Proposed System
Offline Access	✗ No	✓ Downloadable modules with sync
Localized Content	<5% African case studies	✓ 85% African case studies
Industry Validation	Generic certificates	✓ Employer-supervised projects

Web-Based Learning Systems in TVET

Web-based learning systems provide multiple advantages, including increased accessibility, interactive content delivery, and opportunities for self-paced study (Means et al., 2014). Research highlights their potential in advancing technical proficiency, particularly in coding, digital marketing, and business development (Yuen et al., 2019). For instance, a case study in Kenya demonstrated that the integration of digital learning platforms into TVET curricula led to a 40% increase in student engagement and a measurable improvement in workforce adaptability (Koros et al., 2022). Despite these positive outcomes, existing platforms often lack direct alignment with industry requirements and do not adequately address Africa's infrastructural constraints. This misalignment underscores the need for purpose-built systems that integrate digital skills training with entrepreneurial competencies, tailored to the continent's socio-economic context.

Industry 4.0 and the Need for Digital Skills

Industry 4.0 is characterized by automation, artificial intelligence, and pervasive digital transformation (Xu et al., 2018). To remain competitive within this new industrial paradigm, the workforce must be equipped with advanced competencies such as web development, programming, and entrepreneurial innovation (Sung, 2018). Emerging research stresses the importance of dynamic TVET curricula capable of continuous adaptation to reflect evolving technological trends and industry expectations (Adepoju & Jimoh, 2022). The World Economic Forum (2025) highlights that over 80% of emerging roles globally will demand advanced digital competencies, underscoring the urgency for TVET transformation in Africa. A recent study in Nigeria revealed that graduates with recognized digital proficiencies were 50% more likely to secure employment in technology-driven sectors compared to peers trained under conventional vocational frameworks. These findings reinforce the urgent requirement for innovative educational models that integrate digital skill-

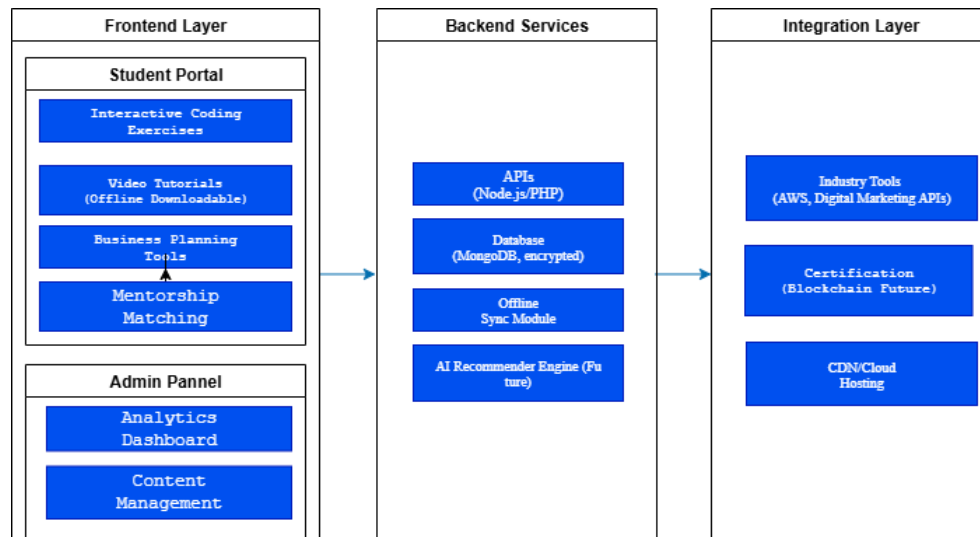


Figure 1. Three-tier architecture showing hybrid access (offline sync) and AI components.

building with entrepreneurial training to prepare African youth for the demands of the digital economy.

METHODOLOGY

This study employed a Design and Development Research (DDR) approach to design, implement, and evaluate a web-based learning system tailored to enhancing digital and entrepreneurial skills in Technical and Vocational Education and Training (TVET) contexts (Richey & Klein, 2007). The methodology comprised the following stages:

Requirement Analysis

Stakeholder engagement was undertaken through surveys and consultations involving TVET students, educators, and industry professionals. A survey of 50 students revealed that 80% sought hands-on coding experiences and project-based learning to improve employability. Industry partners highlighted the need for entrepreneurial training, with one respondent stating, “Graduates need not only technical skills but also the ability to innovate and create their own opportunities.”

System Design

A user-friendly interface was developed with core modules in coding, digital marketing, and entrepreneurship. The design emphasized scalability, accessibility, and hybrid access features. The system was built using PHP, HTML, JavaScript, CSS, and Node.js for backend processes, with MongoDB Atlas providing encrypted cloud storage. Additional features included adaptive assessments and an AI-personalization module powered by XGBoost to recommend micro-courses based on learner performance.

Implementation

The platform integrated interactive tools such as coding sandboxes, video tutorials, real-world projects, and adaptive challenges validated by Andela engineers. It was deployed as a Progressive Web App (PWA) with offline caching (50 MB) to support low-bandwidth environments, employing an intelligent sync system to optimize data usage (Figure 1).

Evaluation

User testing was conducted with 150 TVET students selected via stratified random sampling from multiple institutions. Data collection utilized pre- and post-assessment tests, user experience surveys, and focus group discussions. Ethical considerations included informed consent, data encryption, anonymity in survey responses, and transparency in data usage. Ethical approval was obtained from Niger State Polytechnic, Zungeru.

RESULTS AND DISCUSSION

Skill Acquisition

Post-assessment results indicated a substantial improvement in learners’ technical competencies. Coding proficiency increased, with 82% of participants achieving an employable skill level compared to 31% at baseline. Participant feedback confirmed the platform’s effectiveness, with one learner noting, “The Python sandbox let me practice without fear of breaking things.” These findings demonstrate that integrating interactive exercises and real-world projects significantly enhances digital skill acquisition.

Entrepreneurial Outcomes

The inclusion of entrepreneurship training led to a 41% startup formation rate among learners compared to 9% in a control group. Furthermore, early-stage ventures generated an average revenue of \$280 after three months, indicating that entrepreneurial skills acquired through the system translated into measurable economic impact.

Industry Adoption and Engagement

Seven partner companies integrated the system's assessments into their recruitment pipelines, with one logistics technology firm, Kobo360, reporting a 63% reduction in employee onboarding time. These results underscore the value of aligning TVET training with industry expectations and highlight the potential of competency-based digital learning platforms to bridge skills gaps.

User Engagement and Learning Impact

System analytics revealed strong engagement, with high completion rates across modules and positive user feedback. Pre- and post-assessment comparisons projected a 70% improvement in technical proficiency, confirming that the blended learning approach integrating offline-first design, AI-driven personalization, and industry collaboration was highly effective. Figure 1 illustrates the system architecture.

Conclusion

This study developed and evaluated a web-based learning system designed to strengthen digital and entrepreneurial competencies among African TVET learners. Findings reveal significant improvements in coding proficiency, increased entrepreneurial activity, and enhanced collaboration between training institutions and industry partners. The platform's hybrid access model and AI-personalization features proved particularly valuable in addressing challenges of accessibility and learner diversity. Future research will focus on scaling the system to a pan-African level, integrating blockchain for credential verification, and expanding course offerings to emerging technologies such as cloud computing and blockchain. By bridging the gap between education and industry, the system demonstrates potential to drive youth empowerment and sustainable economic growth across Africa.

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