

DIGITALIZATION AND INNOVATION IN TECHNICAL AND VOCATIONAL EDUCATION AND TRAINING: TOOL FOR TRANSFORMING WORKFORCE FOR SUSTAINABLE DEVELOPMENT IN NIGERIA

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Abstract

Digitalization and innovation are emerging as powerful catalysts for transforming Technical and Vocational Education and Training (TVET) systems globally, particularly in developing countries like Nigeria. This paper explores how the integration of digital technologies and innovative pedagogies in Nigerian TVET can serve as a strategic tool for developing a sustainable and future-ready workforce. As Nigeria grapples with high youth unemployment, skills mismatch, and rapid technological change, digitalizing TVET offers opportunities to improve access, quality, and relevance of vocational training. Through online learning platforms, virtual labs, simulation tools, and competency-based curricula, digital innovation can help bridge the gap between training and labour market needs. Moreover, embedding green skills, entrepreneurship, and digital literacy into TVET programs is essential for supporting Nigeria's transition toward a sustainable economy, in line with the Sustainable Development Goals (SDGs), especially SDG 4. Despite its potential, the digital transformation of TVET in Nigeria faces significant challenges, including inadequate infrastructure, limited digital literacy among teachers and students, funding constraints, and uneven access to technology, particularly in rural areas. This paper concludes that a coordinated, multi-stakeholder approach involving government, private sector, and development partners is crucial to address these barriers. It was suggested amongst others that investing in ICT infrastructure, building digital competencies among TVET educators, updating curricula to reflect green and digital skills, and fostering public-private partnerships to ensure industry relevance. Ultimately, embracing digitalization and innovation in TVET offers Nigeria a viable pathway to equip its growing youth population with the skills needed to drive inclusive growth and sustainable development.

Keywords: *Digitalization, Innovation, Technical and Vocational Education and Training (TVET), Workforce and Sustainable Development.*

Introduction

In the contemporary global economy, the rapid advancement of digital technologies and innovations has fundamentally reshaped how skills are acquired, applied, and transferred in the workplace. Technical and Vocational education and Training (TVET), which traditionally focused on imparting practical and occupational skills, is undergoing a significant transformation to align with the demands of the digital era. This

transformation is driven by the need to prepare a competent, adaptable, and future-ready workforce capable of contributing to sustainable development in an increasingly knowledge-based and technology driven world.

Digitalization in TVET refers to the integration of digital technologies – such as artificial intelligence (AI) machine learning, cloud computing, virtual reality (VR, and mobile learning platforms – into the teaching

, learning, and management processes. These technologies are not only enhancing the quality and accessibility of vocational education but also redefining how skills are delivered and assessed. For example, digital tools facilitate simulations and virtual labs, enabling learners to practice technical tasks in safe, controlled environments without the limitations of physical infrastructure (UNESCO-UNEVOC, 2020).

Furthermore, innovations such as blended learning, e-assessment, and competency-based learning systems are making TVET more learner-centric, efficient, and scalable (ILO, 2021). The innovative transformation of TVET through digitalization also plays a pivotal role in achieving the United Nations Sustainable Development Goals (SDGs), particularly Goal 4 which says(Quality Education), Goal 8 (Decent Work and Economic Growth), and goal 9 (Industry, Innovation and Infrastructure). By equipping individuals with relevant 21st century skills – such as digital literacy, critical thinking, and problem solving – digitally enhanced TVET systems help reduce skill gaps, foster economic inclusivity, and promote lifelong learning (OECD 2019). These systems are especially critical in developing countries, where access to quality education and training remains a major challenge.

Moreover, innovations in TVET are contributing to workforce transformation by creating flexible learning pathways and aligning training with industry 4.0 standards. Industry collaborations, public-private partnerships, and digital credentialing systems are enhancing the relevance of TVET curricula and increasing employability outcomes. For example, Germany's dual vocational training system and Singapore's Skills-Future initiative serve as global benchmarks in integrating workplace learning and technological advancement (World Bank, 2020).

However, this transformation is not without challenges, issues such as digital inequality, limited infrastructure, teacher training gaps, and resistance to change may

hinder the effective implementation of digital innovations in TVET (UNESCO, 2022). Addressing these barriers requires coordinated policy efforts, investment in digital infrastructure, capacity building, and inclusive strategies that ensure no learner is left behind.

Digitalization and innovation in TVET present unprecedented opportunities to reshape education and workforce development in ways that are inclusive, resilient, and future-oriented. As economics transition towards more sustainable and digitalized models, TVET must evolve to become a powerful enabler of socio-economic development, environmental sustainability and technological progress.

Concept of Technical and Vocational Education and Training

Technical and Vocational Education and Training (TVET) refers to education and training that provides individuals with the knowledge, skills, competencies, and attitudes necessary for employment in specific occupations or economic sectors. it encompasses both formal and informal learning processes and is delivered at various levels, from secondary to post-secondary education and beyond. TVET is designed to prepare individuals for the labour market, enhance productivity, foster entrepreneurship, and support lifelong learning for socio-economic development (UNESCO, 2015).

TVET programs are typically skill-oriented and practice-based covering a wide range of fields such as agriculture, construction, manufacturing, healthcare, information technology, and service industries. Unlike general education, which focuses more on academic and theoretical knowledge, TVET emphasizes hands-on training and the development of technical skills directly relevant to specific jobs or industries (OECD, 2010).

According to UNESCO (2016) TVET includes:

- **Technical Education:** - the study of technologies and related sciences and

the acquisition of practical skills related to occupations in various sectors.

- Vocation Education – educational programs that prepare students for specific trades or crafts.
- **Training** – short-term or long-term learning experiences aimed at improving job performance, often through apprenticeships, internships, or on-the-job training.

TVET plays a crucial role in workforce development, particularly in countries seeking to improve productivity, reduce youth unemployment, and respond to the demands of a rapidly changing labour market. It is also a key driver of economic transformation, social inclusion, and poverty alleviation. As such, it is increasingly integrated into national development strategies and education sector reforms (Afeti and Adubra, 2021)

Moreover, TVET systems today are undergoing transformation due to the digitalization of work, globalization, climate change, and demographic shifts. These factors are pushing TVET institutions to modernize curricula, adopt competency-based education models, and strengthen links with industry to ensure that graduates are “work-ready” and possess 21st – century skills such as digital literacy, communication, creativity, and problem-solving (ILO, 2021).

The relevance and quality of TVET depend heavily on several factors, UNEVOC 2020 outline five (5) key areas which include:

1. Curriculum alignment with industry needs
2. Qualified and well-trained instructors
3. Modern equipment and facilities
4. Effective assessment and certification systems
5. Collaboration with employers and other stakeholders.

Government, through national qualification frameworks and public-private partnerships, has increasingly emphasized

these elements to ensure the effectiveness and sustainability of TVET systems. TVET is a vital component of education systems worldwide. It serves as a bridge between education and the world of work, providing individuals with the practical and theoretical foundation to pursue successful careers and contribute meaningfully to their communities and national economies. With the right policy, environment and investment in innovation, TVET can help build a more inclusive, sustainable, and resilient future.

Digitalization in Technical and Vocational Education and Training

Digitalization has emerged as a transformative force across various sectors of society, including education. In the context of Technical and Vocational Education and Training (TVET), digital technologies are reshaping how skills are developed, delivered, and assessed. Digitalization in TVET refers to the integration and application of digital tools, platforms, and practices to enhance vocational training and prepare learners for a rapidly changing labour market driven by the fourth industrial revolution (Industry 4.0)

The need for digitalization in TVET is inherently practical and skill-oriented, often tailored to meet labour market demands. However, the digital transformation of economies worldwide necessitates that vocational education systems evolve. Technological advancements – such as artificial intelligence (AI), robotics, big data, the Internet of Things (IoT), and virtual/augmented reality – are significantly impacting the nature of work. As such, TVET institutions must integrate these technologies to ensure that students acquire relevant digital competencies and are job-ready. TVET systems must respond to technological disruption by embracing digital-solutions that support personalized learning, enhance teacher capabilities, and ensure equitable access to quality training. (UNESCO 2020).

UNIVOC (2021) asserted four key dimensions of digitalization in TVET and the are:

1. Digital Learning Environments
2. Simulation and Immersive Technologies
3. Digital Tools for Teaching and Assessment
4. Industry 4.0 Technologies Integration

Digital Learning Environments:

Digital learning platforms such as Learning Management Systems (LMS), MOOCs (Massive Open Online Courses), and mobile learning apps allow for flexible and remote access to TVET programs. Tools like Moodle, Google Classroom, and Coursera are increasingly being used to deliver vocational content, simulate workplace scenarios, and monitor learner progress.

Simulation and Immersive Technologies:

Technologies like Virtual Reality (VR), Augmented Reality (AR), and digital twins are being employed to simulate real-life working conditions. These tools allow students to engage in hands-on practice without the risks or costs associated with traditional training workshops. For instance, automotive and healthcare training programs now use VR for safe and repetitive skill acquisition.

Digital Tools for Teaching and Assessment:

Digitalization has introduced new forms of assessment such as e-portfolios, gamified tests, and online certifications. Teachers also use digital tools for curriculum design, lesson planning, and data-driven instruction. Artificial Intelligence is increasingly used to provide real-time feedback and personalized learning paths.

Industry 4.0 Technologies Integration:

To align with smart manufacturing and automation trends, TVET institutions are incorporating training in AI, IoT, 3D printing, robotics, and cybersecurity. The inclusion of these competencies ensures that graduates are proficient in digital tools relevant to future workplace.

The benefits of digitalization in TVET according to European Training Foundation (2022) are:

1. Improved Access and Inclusivity: online and blended learning models can reach learners in remote or underserved regions, including marginalized groups such as women, persons with disabilities, and refugees.
2. Enhanced Learning Outcomes: Interactive and immersive technologies improve engagement and retention of skills.
3. Labour Market Relevance: Digitalized training ensures that learners gain skills aligned with current and future job market needs.
4. Efficiency in Delivery: Digital platforms reduce administrative burdens and allow real-time tracking of students' performance.

Digitalization in TVET is not merely an option but a necessity to ensure that vocational education remains relevant and inclusive in the face of technological change. While challenges persist, strategic investments, innovative practices, and strong policy frameworks can drive meaningful transformation. Ultimately, digitalized TVET systems will be better equipped to produce a skilled, adaptable, and digitally literate workforce for the future of work.

Innovations in Technical and Vocational Education and Training

TVET has undergone significant transformation in recent years to meet the demands of a rapidly changing global economy, driven by digitalization, sustainability, and inclusivity. The following are key innovations in TVET according to Tzimas and Demetriadis (2022).

1. Integration of Digital Technologies (e-Learning, Virtual and Augmented Reality).
2. Industry 4.0 and Competency-Based Training (CBT)
3. Green TVET and Sustainable Development

4. Work-Based Learning (WBL) and Apprenticeship
5. Artificial Intelligence and Learning Analytics in TVET
6. Micro-Credentials and Modular Learning
7. Inclusive and Gender-Sensitive Innovations

Integration of Digital Technologies (e-Learning, Virtual and Augmented Reality): Digital transformation is among the most profound changes in TVET. E-learning platforms, simulations, and immersive technologies like Virtual Reality (VR) and Augmented Reality (AR) are now integrated into curricular. A typical examples are the virtual welding simulators in Germany help students learn in a safe, cost-effective environment. AR-enhanced mobile applications are used in Singapore's ITE (Institute of Technical Education) for hands-on skill practice. The benefits is that it enhances student engagement and motivation as well as reduces training costs and safety risks in fields like manufacturing and construction.

Industry 4.0 and Competency-Based Training (CBT): TVET institutions are aligning their programs with industry 4.0 demands (AI, IoT, robotics, automation). Competency-Based Training (CBT) ensures that students acquire measurable and job-relevant skills. In Malaysia, TVET institutions collaborate with industries to design curricula that address technological advancements in smart manufacturing. The German Dual System continues to evolve to incorporate industry 4.0 technologies. The benefits is that there is better alignment with labour market needs at the same it enhanced employability and productivity of graduates.

Green TVET and Sustainable Development: The push for sustainable development has led to the development of Green TVET, focusing on environmentally friendly skills and practices. Example is the Rwanda and Kenya has introduced solar PV installation and maintenance into their curricula. The Philippines TESDA offer green

skills certifications in energy-efficient building construction. These promote sustainability and environmental responsibility and prepare learners for jobs in emerging green sectors.

Work-Based Learning (WBL) and Apprenticeship: WBL models, including modernized apprenticeships and internships, are being enhanced with digital tracking, mentorship platforms, and blended learning. Like the Switzerland's upgraded dual apprenticeship model now includes remote learning components. The UK's Apprenticeship Levy supports digital apprenticeships with e-portfolios and virtual assessments. They improve real-world skills acquisition, strengthens partnerships between TVET institutions and industries.

Artificial Intelligence and Learning Analytics in TVET: AI is used to personalize learning paths, assess student progress, and predict future performance. Learning analytics help tailor instruction to individual needs. Examples are the AI-enabled platforms in China's TVET institutions adapt content based on student performance. Predictive analytics are used in South Korea to identify at-risk learners and intervene early, as these enhances teaching efficiency, improves learner retention and success rates.

Micro-Credentials and Modular Learning: Micro-credentials allow learners to acquire skills in smaller, stackable units that can lead to full qualifications over time. Like the Australia's Skill Organization Pilots promote micro-credentialing in sectors like digital and construction. Courser, edX, and other platforms offer micro-credentials that are now recognized by some TVET systems. The benefit is that it increases flexibility and lifelong learning; enhances access for working learners and those in remote areas.

Inclusive and Gender-Sensitive Innovations: Innovations also target inclusivity, such as programs designed for women, people with disabilities and marginalized communities. Example is Ghana's Skills Development Fund supports training for women in non-traditional fields

like welding and IT. TVET programs in Canada provide assistive technologies for learners with disabilities and this promotes equity and social inclusion and broadens the skilled workforce base.

TVET is being reshaped through technological, environment, and societal innovations. These changes aim to improve the relevance, accessibility, and sustainability of vocational education, equipping learners with the skills needed for a rapidly evolving labour market.

Innovations in Technical and Vocational Education and Training (TVET) in Nigeria

Technical and Vocational Education and Training (TVET) in Nigeria has undergone significant transformation in recent years to address youth unemployment, skill gaps, and technological advancement. Several innovative approaches have been introduced to make TVET more relevant, inclusive, and impactful. Okolie, et al (2020) enumerated seven (7) key areas that has innovations in Nigeria.

1. Integration of Information and Communication Technology (ICT)
2. Competency-Based Training (CBT)
3. Public-Private Partnerships (PPP) and Industry Linkages
4. Use of Mobile Training Units (MTUs)
5. Entrepreneurship and Business Development Integration
6. Digital TVET and Open Distance Learning (ODL)
7. TVET for Green Economy and Renewable Energy Skills

Integration of Information and Communication Technology (ICT): TVET institutions now incorporate ICT into their curricula, offering training in digital skills, coding, robotics, and e-learning platforms. Example of this is the NBTE's learning platforms; the National Board for Technical Education (NBTE) introduced e-learning platforms for Polytechnics, and Monotechnics to support remote leaning and skill

acquisition. Cisco Networking Academies, some technical colleges in Nigeria have partnered with Cisco to offer ICT certifications.

Competency-Based Training (CBT): A shift from theoretical to practical and skill-based learning using competency-based models aligned with labour market needs. Like the National Skills Qualification Framework (NSQF); developed by NBTE to ensure skills' training is demand-driven and outcomes- based. It integrates formal, non-formal, and informal training.

Public-Private Partnerships (PPP) and Industry Linkages: Collaboration between government, private sector, and international organizations to enhance infrastructure, curriculum relevance, and employability. Examples are the Siemens-GIZ Partnership, in partnership with the German development agency GIZ, Siemens has established technical training centers across Nigeria, including in Ogun and Lagos States. Also the Industrial Training Fund (ITF), works with industries to provide technical skills to Nigerian youths through programs like the National Industrial Skills Development Programme.

Use of Mobile Training Units (MTUs): Deployment of mobile workshops and classrooms to deliver skills training in rural and underserved areas. Like the Industrial Training Fund's Mobile Training Units; these units travel to rural communities to deliver practical training in carpentry, welding, tailoring, and ICT.

Entrepreneurship and Business Development Integration: Embedding entrepreneurship training into TVET programs to foster self-employment and innovation. Example is the YouWin! And N-Power Programmes. These include entrepreneurship modules and funding opportunities for young graduates of TVET institutions.

Digital TVET and Open Distance Learning (ODL): Adoption of open distance learning platforms for TVET to expand access, particularly during COVID – 19. Example is the NBTE Virtual TVET Campus,

which was launched to provide access to learners in remote areas, with courses in electronic, agriculture, and IT.

TVET for Green Economy and Renewable Energy Skills: Introducing training in green technologies, climate-smart agriculture, and solar energy installation to meet emerging global sustainability standards. Like the renewable energy training by National Power Training Institute of Nigeria (NAPTIN), offers courses in solar panel installation, energy efficiency, and power system management.

TVET in Nigeria is increasingly becoming more innovative, inclusive, and market-responsive, thanks to the integration of ICT, competency-based learning, partnerships, entrepreneurship and green economy training. These innovations are vital to equipping the Nigerian workforce with 21st century skills.

Workforce Explained

The workforce is the backbone of any economy. It refers to the pool of individuals engaged in or available for work, either in a specific industry, region, or across an entire economy. As global economies rapidly evolve due to technological advancement, demographic changes, and globalization, there is a growing need for a skilled, adaptable, and competent workforce. In this context, Technical and Vocational Education and Training (TVET) plays a critical role in preparing individuals with practical skills, knowledge and competencies that meet the needs of the labour market.

Workforce development refers to a set of strategies and policies that aim to improve the capabilities of workers and increase their productivity. TVET is a central pillar in workforce development as it directly aligns training with the skills demands of employers. The following outlines how TVET contributes to working development as asserted by (African Development Bank 2020)

1. Skill Acquisition and Employability
2. Addressing Skills Gaps and Mismatches

3. Economic Development
4. Youth Empowerment and Employment
5. Lifelong Learning and Adaptability

Skill Acquisition and Employability: TVET provides learners with occupational skills that are directly applicable in the labour market. These skills range from technical, (e.g. welding, electrical installation, carpentry) to soft skills (e.g. communication, problem solving). This alignment enhances the employability of individuals, particularly youth and those disadvantaged backgrounds.

Addressing Skills Gaps and Mismatches: Many economies face the challenge of skills mismatches where workers' qualifications do not meet the demands of employers. TVET systems, when responsive to labour market needs, can reduce these gaps by ensuring that curricula, training methods, and certifications are industry-relevant.

Economic Development: A well-trained workforce boosts national productivity, supports industrial growth, and enhances global competitiveness. Countries that invest in quality TVET systems tend to experience accelerated economic development and improved living standards.

Youth Empowerment and Employment: In many developing countries, youth unemployment is a major issue. TVET offers a viable solution by providing young people with practical skills and opportunities for entrepreneurship or self-employment. It also offers alternative pathways to higher education.

Lifelong Learning and Adaptability: The modern workforce requires continuous re-skilling and up-skilling due to rapid technological change. TVET supports lifelong learning by offering flexible, modular, and competency-based learning approaches that enable workers to adapt and stay competitive in their careers.

TVET plays an indispensable role in workforce development by equipping individuals with job-ready skills, fostering

innovation, and supporting economic growth. As global labour markets continue to evolve, there is a growing need to agile and inclusive TVET systems that respond to the dynamic demands of industries. Strengthening the synergy between TVET and workforce development policies is essential for building a productive, inclusive, and sustainable economy.

An Overview of Sustainable Development

Sustainable development (SD) is a development approach that meets the needs of the present without compromising the ability of future generations to meet their own needs (WCED, 2017). As the global economy and society increasingly confront environmental challenges, socio-economic inequalities, and rapid technological changes, the role of education – especially Technical and Vocational Education and Training (TVET) – has become central to promoting sustainable development.

According to the United Nations (2015) Sustainable development is built on three (3) interconnected pillars namely:

- i. Economic Sustainability
- ii. Social Sustainability
- iii. Environmental Sustainability

Economic Sustainability: This promotes inclusive economic growth, productivity, and employment. It encourages responsible production and consumption, supports innovation and infrastructure development.

Social Sustainability: It ensures access to education, healthcare, and equitable opportunities, advocates for human rights, gender equality, and cultural preservation. Also it aims for social inclusion and reduction of poverty and inequality.

Environmental Sustainability: This focuses on protecting ecosystems and natural resources, addressing climate change, biodiversity loss, and pollution and it encourages the use of renewable energy and conservation practices.

The importance of Sustainable Development is essential for addressing

climate change and environmental degradation; reducing inequality and social exclusion; promoting resilience and adaptability in economies and communities and ensuring intergenerational equity. It fosters long-term development by balancing immediate human needs with environmental protection and responsible resource use. (Sachs (2015).

Pathways to achieve sustainable development is to accelerate progress toward sustainability, stakeholders must adopt integrated policy approaches that link economic, social and environmental goals, invest in education, innovation and green technologies. Strengthen international cooperation and partnerships, support inclusive governance and local community engagement (OECD 2019).

Sustainable development is not only a global necessity but a collective responsibility. It requires balancing growth with equity and ecological integrity. By advancing sustainable development, societies can build a more just, resilient, and thriving future for all. The role of TVET in promoting Sustainable Development is that TVET serves as a strategic driver of sustainable development by preparing individuals and communities to engage in environmentally sound, socially just, and economically viable practices. The integration of Education for Sustainable Development (ESD) into TVET promotes awareness, skills, and values that support sustainability across sectors.

TVET helps in developing a skilled workforce aligned with the demands of green economies. It equips individuals with competencies to engage in renewable energy, energy efficiency, green construction, and sustainable agriculture. TVET fosters social inclusion by offering marginalized groups – such as women, youth, and people with disabilities – access to skills that improve their economic opportunities. It also contributes to social cohesion and resilience. Environmental concerns are integrated into TVET curricula to instill knowledge about environment conservation, climate change

mitigation, and sustainable resource management. UNESCO-UNEVOC 2017).

TVET is a crucial engine for sustainable development. By aligning training with green, inclusive, and equitable growth strategies, TVET can provide individuals with the competencies to thrive in a rapidly evolving world while contributing positively to society and the environment. Governments, international organizations, and stakeholders must therefore prioritize reforms and investments that embed sustainability into TVET systems.

Challenges of Digitalization and Innovations in Technical and Vocational Education and Training in Transforming Work Force for Sustainable Development

Digitalization and innovation have become critical enablers for transforming Technical and Vocational Education and Training (TVET) to meet the evolving demands of the 21st –century workforce and contribute to sustainable development. While digital tools are innovative practices can modernize curricula, enhance learning outcomes, and foster green skills, there are significant challenges hindering their effective integration.

The role of digitalization and innovation in TVET for sustainable development is that digitalization in TVET involves using information and communication technologies (ICT), artificial intelligence (AI), online learning platforms, simulation technologies, and digital tools to improve teaching, learning, and administration.

Innovation refers to adopting new pedagogical approaches, competency-based learning, green technologies, and public-private partnerships to respond to emerging labour market needs and sustainability imperatives. Together, these transformation aim to enhance employability through relevant digital and green skills, improve access to quality TVET, especially in underserved regions, build a flexible, resilient workforce equipped for future challenges. (UNESCO-UNEVOC 2020)

The major challenges of digitalization and innovation in TVET according to CEDEFOP (2020) are:

1. Infrastructure and Technological Gaps
2. Digital Literacy and Skills Deficit
3. Financial Constraints
4. Pedagogical and Curriculum Rigidities
5. Inequity and Digital Divide
6. Resistance to Change and Institutional Inertia
7. Lack of Industry Collaboration and Innovation Ecosystems

Infrastructure and Technological Gaps. Many TVET institutions, particularly in developing countries, face limited access to essential ICT infrastructure including computers, internet connectivity, electricity, and digital labs. Rural-urban divide deepens inequality in access to digital tools and outdated equipment in training centers hampers the ability to teach modern technologies.

Digital Literacy and Skills Deficit: Both TVET instructors and learners often lack digital literacy and skills to effectively use and adapt to new technologies. Instructors may be unfamiliar with Learning Management Systems (LMS), AR/VR tools, or digital content creation. Students may not possess foundational digital competencies, especially those from marginalized backgrounds.

Financial Constraints: Digital transformation in TVET requires substantial investment in infrastructure (hardware, software), training and professional development, curriculum design and content development. Many countries struggle with underfunded TVET sectors and competing priorities, leading to slow adoption of innovations.

Pedagogical and Curriculum Rigidities: TVET systems often rely on traditional, workshop-based models, making it difficult to integrate flexible, technology-enabled and innovation-oriented teaching methods; lack of competency-based or problem-based learning. Inflexible national

curricula that delay innovation integration and misalignment between digital skills taught and labour market needs.

Inequity and Digital Divide: Digitalization risks exacerbating educational inequality, particularly among women and girls, who are underrepresented in tech-related TVET programs; people with disabilities that may face accessibility barriers; refugees, migrants, and people from low-income households.

Resistance to Change and Institutional Inertia: Institutional culture often resists innovation due to uncertainty or lack of motivation. Teachers and administrators may feel overwhelmed by new digital responsibilities without adequate support.

Lack of Industry Collaboration and Innovation Ecosystems: Effective TVET transformation depends on collaboration with industries, but many systems face weak or outdated links with employers and tech providers, lack of labour market information to anticipate digital and green skills and few public-private partnerships for innovation in curriculum and training.

Digitalization and innovation in TVET hold immense potential to transform the workforce in alignment with sustainable development goals. However, without deliberate action to address systemic, infrastructural, pedagogical, and equity challenges, TVET may fall short of its transformative promise, governments, educators, industries, and international partners must work together to re-imagine TVET as a resilient, inclusive, and future-ready system.

Digitalization and Innovation in Technical and Vocational Education and Training; a tool for Transforming Workforce for Sustainable Development

In the 21st century, global economies face unprecedented challenges and opportunities stemming from rapid technological advancements, environmental crises, and socio-economic disruptions. To address these challenges and achieve the United Nations

Sustainable Development Goals (SDGs), particularly SDG 4 (quality education and SDG 8 (decent work and economic growth), Technical and Vocational Education and Training (TVET) must be transformed. Digitalization and innovation have emerged as powerful tools for this transformation, equipping learners with skills that are relevant, future-oriented, and sustainable.

Digitalization in TVET refers to the integration of information and communication technologies (ICTs), online learning platform, simulation tools, artificial intelligence (AI), and other digital tools into teaching, learning, and administrative processes. Innovation encompasses new teaching methodologies, competency-based learning, public-private partnerships, green technologies, and modernized curricula that respond to evolving labour market needs and sustainability challenges. Together, these forces can transform TVET systems from traditional, manual instruction to dynamic, digital ecosystems capable of producing a skilled, adaptable, and sustainability-conscious workforce. (UNESCO-UNEVOC 2020).

The transformative role of digitalization and innovation in workforce development according to ILO (2021) are:

Enhancing Access, Flexibility and Lifelong Learning: Digital platforms expand access to TVET by allowing learners to participate from remote and underserved areas. E-learning, mobile apps, and virtual labs offer flexible learning opportunities that support lifelong learning, critical in an era of rapid technological change. Example of this is the Kenya's TVET authority partnered with digital providers to deliver online training during COVID-19, increasing inclusivity.

Developing Digital and Green Skills: As economies transition toward automation and sustainability, workers need digital literacy, coding, data analysis, and green skills such as energy efficiency and sustainable resource management. Digital tools enable simulations and problem-based learning that help trainees develop these competencies.

Promoting Industry 4.0 Readiness: Digitalization in TVET prepares learners for Industry 4.0 – a world of smart manufacturing, robotics, IoT, and AI. By aligning curricula with emerging technologies, TVET institutions can ensure that graduates are work-ready and responsive to changing labour market demands. German and Singapore incorporate AI and robotics into vocational training to future-proof their workforce.

Encouraging Innovation and Entrepreneurship: Digital technologies foster creativity, innovation, and entrepreneurship by providing learners with tools to design solutions to real-world problems. This supports the development of green enterprises and socially responsible startups that contribute to sustainable development.

Empowering Marginalized Groups: Digital platforms can bridge gaps for marginalized populations- such as women, youth, refugees, and persons with disabilities – by offering inclusive and adaptable learning environments. This supports social sustainability by enhancing equity and social mobility.

Contribution to Sustainable Development Goals (SDGs): Digitalization and innovation in TVET directly support several SDGs and they are SDG 4.4; improve the number of youth and adults with relevant skills for employment, decent jobs, and entrepreneurship, SDG 8.6; substantially reduce the proportion of youth not in employment, education, or training (NEETs), SDG 9, build resilient infrastructure and foster innovation and SDG 12, ensure sustainable consumption and production patterns.

Digitalization and innovation have the potential to revolutionize TVET, turning it into a cornerstone of workforce transformation of sustainable development. By embracing these tools, TVET systems can become more inclusive, relevant, and future-ready, capable of producing skilled professionals who not only drive economic growth but also contribute to environmental

protection and social cohesion. Governments, development partners, and industry stakeholders must therefore commit to embedding digital and innovative strategies at all levels of TVET.

Conclusion

Digitalization and innovation are no longer optional in the evolution of Technical and Vocational Education and Training (TVET); they are imperative tools for transforming the workforce in alignment with the global pursuit of sustainable development. As economies undergo rapid digital transformation and shift towards environmentally sustainable practices, the ability of TVET systems to adapt and lead in this transition is critical.

By integrating digital technologies – such as e-learning platforms, simulation software, artificial intelligence, and data analytics – TVET institutions can improve the accessibility, flexibility, and relevance of skills training. Simultaneously, embracing pedagogical and institutional innovations, including competency-based education, green skills development, and public-private partnerships, equips learners with the capabilities to succeed in an increasingly complex and sustainability-driven labour market.

The transformative potential of digitalization and innovation in TVET extends beyond just economic outcomes. It also fosters social inclusion by providing marginalized groups with opportunities to participate in and benefit from modern education and employment. Moreover, it contributes to environmental sustainability by embedding ecological awareness and sustainable practices into skills training across sectors.

However, the full realization of this potential requires deliberate and coordinated action. Policymakers, educators, industry stakeholders, and development partners must work collaboratively to address persistent challenges such as infrastructure deficits, digital illiteracy, funding constraints, and equity gaps. Investments in educator training

curriculum reform and inclusive digital ecosystems are essential to ensure that digitalization and innovation contribute meaningfully to the achievement of the Sustainable Development Goals (SDGs).

In essence, transforming TVET through digitalization and innovation is not merely a response to global trends – it is a strategic imperative to build a resilient, future-ready, and sustainability-oriented workforce. With the right vision and commitment, TVET can serve as a powerful engine for inclusive growth, green economies, and a more equitable and sustainable future for all.

Suggestions for the Way Forward

To effectively harness digitalization and innovation in TVET as a transformative tool for workforce development and sustainable growth, a multi-pronged, inclusive, and strategic approach is required. The following suggestions outline key areas of intervention for policymakers, educational institutions, industries and development partners:

1. Strengthen digital infrastructure and connectivity; invest in ICT infrastructure across all TVET institutions, especially in rural and underserved regions. Ensure reliable electricity, internet access, and hardware (computers, smart boards, etc) to enable digital teaching and learning. Develop centralized national digital learning platforms to host TVET resources and curricula. This will form the technological backbone for effective digital transformation in TVET.
2. Build educator capacity for digital and innovative teaching; provide continuous professional development for TVET instructors in digital tools, online pedagogy, instructional design, and blended learning methods. Encourage peer learning and knowledge exchange platforms among teachers at national and regional levels. Recruit digital specialists to support curriculum digitization and

capacity-building programs. Teachers are the frontline enablers of digital and innovation-driven TVET systems.

3. Embed digital, green, and entrepreneurial skills into TVET curricula; update national TVET qualifications to include 21st-century competencies such as digital literacy, coding and data management, sustainable practices and green technologies, critical thinking and entrepreneurship. Use project-based, experiential and competency-based learning approaches to improve real-world application of knowledge. An updated curriculum ensures TVET graduates are prepared for emerging and sustainable job markets.
4. Foster Industry Partnerships and Innovation Ecosystems, establish strong public-private partnerships (PPPs) to co-create digital content, facilitate apprenticeships, and guide curriculum relevance. Involve industry experts in the development of TVET innovation hubs where students can engage in real-time problem-solving. Encourage investment from the private sector in digital labs, tools and skill-building programs. Industry collaboration bridges the gap between education and labour market needs.
5. Ensure Inclusive and Equitable Access to Digital TVET; design inclusive policies and programs to address gender disparities, support learners with disabilities, and reach marginalized groups. Provide scholarships, digital devices, and subsidized internet access for disadvantaged learners. Develop multilingual and culturally sensitive digital content to increase accessibility. Equity in digital TVET is essential to ensure no one is left behind in workforce transformation.
6. Promote Policy Coherence and Governance; formulate national digital TVET strategies aligned with sustainable development goals and

labour market forecasts. Set up multi-stakeholder governance structures to coordinate efforts among ministries (education, labour, ICT environment), private sector, and civil society. Establish data-driven monitoring and evaluation systems to assess the impact of digitalization and innovation in TVET. Sound governance and policy coherence ensure sustainable and scalable change.

7. Encourage Innovation and Research in TVET; support action research, pilot programs, and innovation incubators within TVET institutions to test new digital and green methodologies. Document and scale up best practices and success stories from local and international contexts. Foster international cooperation and south-south collaboration for knowledge exchange and technology transfer. Innovation must be embedded in the DNA of TVET institutions to remain relevant and future-ready.
8. Facilitate Lifelong Learning through Digital Platforms; develop modular, self-paced, and micro-credentialed online courses for up-skilling and re-skilling. Create national skills development portals where individuals access TVET resources across their careers. Integrate recognition of prior learning (RPL) systems with digital certification pathways. A digitally connected TVET system supports a dynamic and lifelong learning culture.

Realizing the full potential of digitalization and innovation in TVET demands a visionary, inclusive, and sustained commitment. By modernizing infrastructure, building educator capacity, reforming curricula, engaging industry, and ensuring equity, TVET can become a powerful catalyst for workforce transformation and sustainable development. These efforts must be guided by data, supported by policy, and driven by

collaboration to create a resilient, green, and future-ready global workforce.

References

- Afeti, G., & Adubra, A. L. (2021). Lifelong technical and vocational skills development for sustainable socioeconomic growth in Africa. African Union.
- African Development Bank (2020) Skills for employability and productivity in Africa, AFDB publications.
- CEDEFOP (2020). European centre for the development of vocational training.
- European Training Foundation (ETF) (2022). Digital skills and TVET teachers. Retrieved from <https://www.etf.europa.eu>.
- ILO (2021). Skills for a resilient youth in the post-pandemic era. International Labour Organization. <https://www.ilo.org>.
- ILO. (2021). Skills development in the time of COVID – 19. Taking stock of the initial responses in technical and vocational education and training. International Labour Organization. <https://www.ilo.org>.
- OECD (2010). Learning for jobs. OECD reviews of vocational education and training. Organization for Economic Co-operation and Development. <https://www.oecd.org>.
- OECD (2019). Measuring distance to the SDG targets 2019). An assessment of where OECD countries stand.
- OECD. (2019). Future of Education and Skills 2030. Conceptual learning framework. Organization for Economic Co-operation and Development. <https://www.oecd.org>.
- Okolie, U. C. et al (2020). ICT integration in TVET. Challenges and opportunities in Nigeria. Education and Information Technologies, 25 (5), 4453 – 4474.
- Sachs, J. D. (2015). The age of sustainable development. Columbia University Press.
- Tzimas, E., & Demetriadis, S. (2022). Virtual and Augmented Reality in Vocation

- Education. A meta-analysis computer and education, 184, 104525. <https://doi.org/10.116/j.compedu.20>.
- UNESCO – UNEVOC. (2020). Digitalizing TVET: Guidelines for designing and implementing effective digital training solutions. <https://unevoc.unesco.org>.
- UNESCO, (2022). Building skills for tomorrow. Digitalization of TVET systems in response to COVID – 19. UNESCO Publishing.
- UNESCO. (2015). Recommendations concerning Technical and Vocational Education and Training (TVET). United Nations Educational, Scientific and Cultural Organization. <https://unesdoc.unesco.org>.
- UNESCO. (2016). Strategy for technical and vocational education and training (TVET) 2016-2021. UNESCO Publishing.
- UNESCO-UNEVOC (2017). Greening technical and vocational education and training: A practical guide for institutions. Bonn. UNESCO-UNEVOC.
- UNESC-UNEVOC. (2020). TVET in the 21st Century: New challenges and opportunities. <https://unevoc.unesco.Org>.
- United Nations (2015). Transforming our world. The 2030 Agenda for Sustainable Development. Vocational education and training systems in transition.
- WCED (1987) Our Common Future. World Commission on Environment and Development (Brundtland Report).
- World Bank. (2020). Skills for a resilient youth in the era of COVID – 19 and beyond. World Bank Group. <https://www.worldbank.org>.