IMPLICATIONS OF INFORMATION AND COMMUNICATION TECHNOLOGY REVOLUTION FOR TECHNICAL VOCATIONAL EDUCATION AND TRAINING IN POST COVID-19 PANDEMIC

Bala M. Mohammed[1,*], Abdullahi M. Hassan[2], Audu Rufa'i[3], Dauda Ibrahim[4], Wahab B. Kareem[5] and Abdul B. Kagara[6]

[1,2,3,4,5,6]*Department of Industrial and Technology Education, Federal University of Technology, Minna*

*Corresponding E-mail: balmak58@yahoo.com (Tel: +2348024916900)

Abstract: *The Information and Communication Technology (ICT) has continue to gain momentum within framework of potential efforts and strategies to boost all faucets of human endeavours among which is acquisition of skills in Technical, Vocational Education and Training (TVET) for life-skills and life learning that could lead to employment and job creation in today's new economy. The impact of Covid-19 has brought about many challenges that include changes in ways of life that affects work, relationships, economy, choices, education, business, and many more. TVET has a greater role to play in making sure that its students and the existing technical workforce are given appropriate training to remain employable in the new economy of post Covid-19. Regrettably, many graduates of TVET do not poses computer soft skills required for job success in post Covid-19. This paper reviewed the VLEs currently in use for theory lessons and identified Artificial Intelligence (AI) as appropriate online technology that should be used for lesson delivery considering the nature of TVET and the resultant challenges of covid-19 pandemic. The paper also identified areas of application of AI in industries in which training is conducted in TVET. The paper recommended among others that TVET institutions should begin planning and commencement of AI programmes towards workforce upgrade for the new economy.*

Keywords: *TVET, COVID-19, ICT, New Economy, Artificial Intelligence*

Introduction

It is clear that Information and Communications Technology (ICT) has emerged as a formidable force with the potential to transform Technical, Vocational Education and Training (TVET) for a new economy in which gaining digital literacy and knowledge of the effective and creative use of ICTs has never been more important. The most important features of TVET are its orientation towards the world of work and the emphasis of its curriculum on the acquisition of employable skills. Hence, the emphasis on psychomotor domain that deals primarily with physical or practical skills development in TVET. However, Key practical challenges of increasing the use of ICTs in TVET (lack of infrastructure, high initial cost & on-going costs, security issues, environmental issues for equipment, need to upgrade staff skills & development, managing constant change & upgrades) remain deadly treats to achieving this heroic task. The covid-19 pandemic is the biggest disruption education has witnessed in recent history. The impact of Covid-19 crises added to the global challenges faced by the education industry (Changes in ways of life that affects work, relationships, economy, choices, education, business, and etcetera). TVET has a challenging role to play in making sure that the existing technical workforces possess needed skills to remain employable in the new economy. What are the appropriate online technologies, that is, Virtual Learning Environments (VLE) available for different types of learning in TVET in post Covid-19 era?

TVET system in Nigeria

The success of TVET in any developing country can be considered a key indicator of the country's advancement in development. UNESCO (2011) recognizes this fact when it stated that TVET is a prerequisite for sustaining the complex structure of modern civilization and economic and social development. A quality TVET programme help to promote a country's economic growth, contribute to poverty reduction as well as ensures the social and economic inclusion of marginalized communities (UNESCO 2013). The united nation has placed so much emphasis on TVET such that it continues to coordinate its development worldwide for quality assurance. Thus,

any country that evolved into a technological advanced one, TVET must have played an active and vital role, as skilled work force would have been required, also to enable its sustainability. According to Atchoarena & Delluc (2001), TVET refers to education, which is mainly to lead participants to acquire the practical skills, knowhow and understanding necessary for employment in a particular occupation, trade or group of occupations. Uwaifo (2010) defined TVET as the training of technically oriented personnel who are to be the initiators, facilitators and implementers of technological development of a nation by adequately training its citizenry on the need to be technologically literate, leading to self-reliance and sustainability. TVET as defined by UNESCO (2001) and adopted by the Federal Republic of Nigeria in her national policy on education (2014 p. 29) is:

> *"Referring to those aspects of the educational process involving in addition to general education, the study of technologies and related sciences and the acquisition of practical skills, attitudes, understanding and knowledge relating to occupations in various sectors of economic and social life"*

TVET is:

- An integral part of general education;
- A means of preparing for occupational fields and for effective participation in the world of work;
- An aspect of lifelong learning and a preparation for responsible citizenship;
- An instrument for promoting environmentally sound suitable development
- A method of alleviating poverty

The goals of TVET in Nigeria as further stated in the national policy on education are to:

- Provide trained manpower in the applied sciences, technology and business particularly at craft, advanced craft and technical levels;
- Provide the technical knowledge and vocational skills necessary for agricultural, commercial and economic development;
- Give training and impart necessary skills to individual who shall be self-reliant economically.

A glean from the above, TVET broadly refers to deliberate interventions to bring about learning, which would make people adequately productive in designated areas of economic activity such as, economic sectors, occupations, and specific work tasks. TVET thus equips people not only with vocational and technical skills, but also with a broad range of knowledge, skills and attitudes recognized as indispensable for meaningful participation in work and life. It is the goal of TVET to prepare learners for specific jobs or types of work, often including practical and/or procedural activities. TVET can take place either in formal schools (primary through post primary schools/ technical colleges, polytechnics and the universities), or informally (training at the workplace, enterprise and apprenticeship training centers as well as by distance media). In Nigeria traditional apprenticeship offers the greater opportunity for the acquisition of employable skills in the informal sector, while formal TVET programmes are school-based. The covid-19 crises has brought about greater challenges that have made stake holders in the education industry to embrace the use of Distance Learning (DL) for the covid-19 pandemic era.

The national policy on education (Federal Republic of Nigeria, 2014), presented technical and vocational subjects at all levels of education. The duration of the school-based TVET in the 9-3-4 educational system, is nine years pre-vocational skills at primary and junior secondary schools. Higher vocational skills are offered for three years and four years at senior secondary school and tertiary institutions respectively. Developing effective school-based curriculum at the various levels of TVET for DL in life-skills and life learning must be based on psychomotor theoretical concepts. It is important to survey the taxonomy of the psychomotor domain before examining the appropriateness of ICTs for teaching and learning practical skills in TVET.

The psychomotor domain has five main categories (Dave 1975):

1. ***Imitation:*** The learner goes through a period of trial and error to imitate an act that has been explained and demonstrated.
2. ***Manipulation:*** The learner practices the skills until some level of competence is attained.
3. ***Precision:*** The learners continue to practice until they attain the competency requirement.
4. ***Articulation:*** The learners attain higher-level expertise that allows them to solve problems.
5. ***Naturalization:*** The learners reach a stage where responses can be automatic (routine).

It is interesting to note that only during the imitation stage does the learner need explanation and demonstration. During the manipulation, precision, articulation, and naturalization stages, the learner can practice independently to perfect their skills. Consequently, the imitation stage is the most critical phase of practical skills development, because it requires most guidance and support in VLE. It is important to note that the teaching of practical skills would always require the support of skilled instructors and a range of tools or equipment.

How Learning Takes Place

Learning occurs through five senses and in varying amounts. Following is estimated amount of learning from the five senses (Kupsh & Mason, 1986):

- ✓ Taste: 1%
- ✓ Touch: 1.5%
- ✓ Smell: 3.5%
- ✓ Hearing: 11%
- ✓ Seeing: 83%

The amount of information that people retain is also an important aspect of learning. Kupsh and Mason (Table 1) also provide some interesting insights regarding the amount of retention through the various senses over time:

Table 1: Retention of Learning

	After 3 hours (%)	After 3 days (%)
Material heard only	70	10
Material seen only	72	20
Material both heard and seen	85	65

ICT tools for teaching psychomotor skills

The learning of practical skills is most often associated with workshops and laboratories, specialist materials and equipment, smaller class sizes and, frequently, longer blocks of time for practice and rehearsal. It involves the mind and body coordination to perform a task; it also requires the learner to manipulate certain objects in order to demonstrate creativity and to perform a task. ICTs in common use for teaching and learning include: audiocassette tapes, radio, videotapes, CD-ROM, the Internet, wire line technology, wireless technology, web-based training, audio conferencing, audio graphics, interactive television, videoconferencing, and open and distance learning. When technology is used as a delivery mechanism the focus is on packaging course content for digital delivery. Common approaches in current use include computer-assisted instruction (CAI), computer-based instruction (CBI), and web-based or online instruction. Open and Distance Learning (ODL) programmes make extensive use of technology as their delivery mechanism.

For the VLE, the teaching of practical skills poses more difficulties than the teaching of knowledge and theory. Haddad and Draxler (2002) noted however that the inability to meet the challenge is self-inflicted because of a tendency to use Industrial Age models to solve Artificial Intelligence (AI) Age problems. VLE include:

- ✓ MOODLEs and blackboard,
- ✓ web-based learning environments,
- ✓ virtual reality settings such as Second Life,
- ✓ software that aims to teach skills,
- ✓ educational games and simulations,
- ✓ use of discussion forums to promote learning, and
- ✓ knowledge exchange, among others.

Simulators are often used in TVET to address safety concerns during the initial phase of training and to offset cost in renting equipment for training crane operators and truck drivers. In its simplest form, technology can be used for drill and practice to complement instruction. Most VLEs are designed for theory lessons and are not suitable for teaching and learning skills. The question is, what appropriate online technology will provide interactive educational content delivery befitting of the new economy?

Artificial intelligence in TVET

The increasing need for intelligent and accurate decision-making across industries has led to an exponential growth in the adoption of AI and Machine Learning (ML) technologies, which will remain relevant in years to come. Villani (2018) captured the emergence of artificial intelligence in one sentence; "We have entered an era in which all, or almost all, phenomena can be measured and quantified using all kinds of sensors and models". Artificial intelligence refers to the simulation of human intelligence in machines. Machines are programmed to think like and mimic the actions of humans. The term also applies to any machine that exhibits traits associated with a human mind such as learning and problem solving as in the case of TVET. Artificial intelligence, sometimes called machine intelligence, is intelligence demonstrated by machines, unlike the natural intelligence displayed by humans and animals (Wikipedia, 2020). Hindi (2020) defined AI as a field of research that involves providing machines with autonomous behavior. Artificial intelligence (AI) is a set of technologies and building blocks, all utilizing data to unlock intelligent value across industries and businesses (Zohuri & Rahmani, 2019). Autodesk (2020) described the role of AI as an augmentation to human work. Busch (2017) defines AI as a constellation of technologies that allow smart machines to extend human capabilities by sensing, comprehending, acting and learning—thereby allowing people to achieve much more. Deducting from the definitions above, AI refers to the simulation of human intelligence in machines. While human develops the broad strategy, a machine takes care of the calculations.

In light of this encompassing definition, a new economy is born (#6, Table 2) which is knowledge and idea-based economy where the keys to job creation and higher standards of living are innovative ideas and technology embedded in services and manufactured products driven by AI. Four types of AI are reactive machines, limited memory, theory of mind and self-awareness (Wikipedia, 2020). AI is a new and emerging education and training pathways in the world today. According to Busch (2017), education will see a boost in GVA from 0.9 percent to 1.6 percent by 2035 and manufacturing from 2.1 to 4.4 percent. On industry outputs, education is one of the lowest, 1.1 to 1.2; however, for the impact of AI on profits by industry: education is expected to top other industries with 84% profit by 2035. The reason for the low industry inputs is that AI is not targeting human jobs but rather provides a reach database on which teachers and students can build their skills and help in decision-making. The covid-19 pandemic has further reshaped the economies of the world to a new economy #6 (see Table 2).

Table 2: Six "New Economies"(Source: Adapted from Kafka, 2013)

Also known as	Period		Main symbols
New Economy #1	The Industrial Revolution	1787–1842	Cotton textiles, Iron, Steam power
New Economy #2	The Bourgeois Kondratieff	1842–1897	Railroads
New Economy #3	The New-Mercantilist Kondratieff	1897–1939	Electricity, Automobile
New Economy #4	The Cold-War Kondratieff	1939–1989	Defense, Television, Mainframe computers
New Economy #5	The Information Age	1989–2020	Personal computers, Telecommunications, Entertainment
New Economy #6	The Artificial Intelligence Age	2020-????	AI, ML, Robotics

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AI-powered systems deliver constantly rising rates of return due to their ability to learn, adapt and evolve over time. There will be a need for new skills in the workforce that integrate technical expertise, with a new emphasis on human abilities—judgment, communication, creative thinking—that complement technologies (Busch, 2017). Purdy (2017) states the potential of AI as the new factor of production:

> "AI can drive growth in at least three important ways. First, it can create a new virtual workforce—what we call intelligent automation. Second, AI can complement and enhance the skills and ability of existing workforces and physical capital. Third, like other previous technologies, AI can drive innovations in the economy. Over time, this becomes a catalyst for broad structural transformation as economies using AI not only do things differently, they will also do different things."

The computer is programmed to learn increasingly abstract concepts, and to combine these different concepts with one another. ML is a branch of AI that seeks to provide the machine with examples of behavior, which enable it to learn to recreate such behavior itself. For example, if the picture of a building or furniture is imputed into the computer, it would process the outlines of the shape of the object, learn the concept of an outline, and then combine the outlines to recreate the image of the face of that object. Data is the raw material used to produce artificial intelligence. Teaching psychomotor skills in design, manufacturing and production is possible using AI to recreate design and manufacture products. AI will perform manufacturing, quality control, shorten design time, and reduce materials waste, improve production reuse, perform predictive maintenance, and much more including:

Education: Educators armed with data-driven insight can make a significant impact on school systems, students, and curriculums (Zohuri & Rahmani, 2019). Education systems must be responsive to labour market demands. By analyzing big data, educators can identify at-risk students, ensure students are making adequate progress, and can implement a better system for evaluation, decision-making and support of teachers and principals. Haddad and Drexler (2002) identified five different hierarchical levels of education where ICTs can be used: presentation, demonstration, drill and practice, interaction, and collaboration. The levels and technologies are outlined below (Table 3):

Table 3: Appropriate Technology for Different Teaching Levels (Source: Haddad & Drexler, 2002)

	TECHNOLOGY					
Use	**Text**	**Audio**	**Video**	**Computer**	**Internet**	**Text**
Presentation	X	X	X	X	X	X
Demonstration	X	X	X	X	X	X
Drill and Practice	X	(e.g. language lab)			X	X
Interactive	hyperlink			X	X	X
Collaborative					Networked	X

Selecting a technology or a combination of technologies for teaching and learning depends on factors such as available infrastructure, pedagogical constraints, learners' characteristics, subject matter, content, and time available to teach and learn. ICTs allow the delivery of education to adapt to an individual needs as opposed to having the individual adapt to how the education is delivered. Education will not be confined to the four walls of a classroom but to wherever and whenever the learner deems appropriate. The question is, what appropriate online technology will provide interactive educational content delivery befitting of the new economy?

Effects of globalization and ICTs on TVET skills

The decline of industrial jobs in advanced economies is only partially related to globalization; technological change has had more profound impact on the labour market, because "today's workplaces are often in multi locations characterized by cultural diversity. Advancement in technology has helped to reduce production workforce and economies of scale, thus boost industrial productivity, and causing a movement of labour from industry to the service sector. There seems to be no consensus regarding the impact of technological change on the workplace and its effects on jobs and skills, hence, life-skills and lifelong learning has become dynamic. ICTs can downsize skills and competence to single-task machine tending, and can upgrade skills and competence to multi-task work relying on greater creativity. When a machine performs jobs that were used to be done by skill labour, it reduces the skill requirement of the artisan in what may be referred to as de-skilling; whereas, the soft skills and machine maintenance skills that will most certainly be required, are up-skilling jobs for life-skills and lifelong learning. AI is already making global impact in the following skill areas:

1. ***Quality Checks:*** Machine vision allows machines to "see" the products on the production line and spot any imperfections. Some defects in products too small to be noticed with the naked eye, can be detected by machines equipped with cameras many times more sensitive than the human eyes.
2. ***Prediction of Failure Modes:*** We can make false conclusions concerning products and processes. Products can fail in a variety of ways, irrespective of the visual inspection. A product that looks perfect may still break down soon after its first use. Similarly, a product that looks flawed may still do its job perfectly well. The way we observe objects and flaws is biased and many things may be different than they seem. AI can use vast amounts of data on how products are tested and how they perform, to identify the areas that need more attention in tests.
3. ***Predictive Maintenance:*** Predictive maintenance allows companies to predict when machines need maintenance with high accuracy. Predictive maintenance prevents unplanned downtime by using ML technologies such as sensors and advanced analytics embedded in manufacturing equipment. By analyzing the data, our AI systems can draw conclusions regarding a machine's condition and detect irregularities in order to make predictive maintenance possible.

4. ***Generative Design:*** Generative design is a process that involves a program generating a number of outputs to meet specified criteria. Designers or engineers input design goals and parameters such as materials, manufacturing methods, and cost constraints into generative design software to explore design alternatives. The solution utilizes ML techniques to learn from the iteration what works and what does not, and use algorithm to find countless ways of designing a simple thing (chair, table, and etcetera). Computational design does not replace human creativity but rather aids and accelerates the process, expanding the limits of design and imagination.

5. ***Digital Twins:*** A digital twin is a virtual representation of a factory, product, or service. The representation matches the physical attributes of its real-world counterpart using sensors, cameras, and other data collection methods. The ultimate vision for the digital twin is to create, test and build desired equipment in a virtual environment. Only where it performs to the requirements it is then physically manufactured. The physical build is tied back to its digital twin through sensors so that the digital twin contains all the information that could be obtained by inspecting the physical build.

6. ***Environmental Impact:*** AI could help to transform manufacturing by reducing, or even reversing its environmental impact. Extraction of nickel, cobalt, graphite for lithium-ion batteries, increased production of plastic, huge energy consumption, e-waste – just to name a few. AI can support developing new eco-friendly materials and help optimize energy efficiency.

7. ***Price Forecasts:*** To manufacture products, first there is need to purchase the necessary resources, and sometimes the prices can become unstable. For example, the price of stainless steel is affected by a variety of factors, including the listings of Metal Exchange or the prices of other elements, some of which are not listed on the metal exchange. With the rapid changes in prices, sometimes it may be hard to assess the best time to buy resources. Knowing the prices of resources is also necessary for companies to estimate the price of their products. The system is able to provide accurate price recommendations just like in the case of dynamic pricing used by e-commerce businesses like Amazon where machine-learning algorithms analyze historical and competitive data to always offer competitive prices and make even more profit.

8. ***Robotics:*** Conventional industrial robots are specifically programmed to carry out the tasks they are created to do. The conventional robots need to be provided with a fixed procedure of assembling parts; however, AI-powered robots can interpret CAD models, which eliminate the need to program their movements and processes. However, soft skills and machine maintenance skills that will most certainly be required are up-skilling jobs for life-skills and lifelong learning.

9. ***Customer Service:*** Hospitality, retail, banking, and many other industries deal with customers directly. Therefore, customer service is a huge part of their business. In manufacturing, however, the importance of customer service is often overlooked – which is a mistake as lost customers can mean millions of dollars in lost sales. AI solutions can analyze the behaviors of customers to identify patterns and predict future outcomes. AI will allow service providers to quickly identify issues and prioritize improvements faster and more efficiently in a variety of ways.

The effects of globalization and advancement in technology on today's new economy

1. ***Climate for Growth***

   (a) No apparent threat of recessions

   (b) Expansion without increased inflation

   (c) No excessive debt

   (d) Balanced budget

2. ***Knowledge and Brain Power***

   (a) Life Skills and Life-long learning

   (b) Digital literacy

   (c) Machine intelligence

   (d) Self-paced learning

   (e) Just-in-time education

   (f) Any place and any pace

   (g) Ability to innovate and learn

   (h) Learning how to learn

3. ***Industrial and Occupational Change***

   (a) More people work in offices

   (b) More people work in service sector jobs

   - Improvement in processes, products and services
   - Dominance of machines on physical labour

   (c) Growth in high-skills and low-skills jobs

   - Soft skills basic in product manufacturing
   - Real time virtual industries

   (d) Increase in knowledge jobs requiring post-secondary, vocational or higher education

4. ***Globalization***

   (a) Increased international trade

   (b) Intensive competition

   (c) Innovation key to prosperity

   (d) Increasingly globalized and export driven

   (e) Competition-induced time-to-market consideration

   (f) Short product lifecycles

5. ***Dynamism and Competition***

   (a) Fast growing entrepreneurial companies

   (b) Embracement of entrepreneurial dynamism by investors

   (c) Networking and cooperation

   (d) Driver of innovation and growth

   (e) Mass customization and flexible production to meet customers' needs

   (f) Insecurity, instability and economic risks for workers

6. ***The Information Technology Revolution***

   (a) Omnipresence of microchips

   (b) Dramatic decrease in price of computing

   - Decrease in data cost facilitates global communications

The new economy is one where risk, uncertainty, competition and constant change are not the exception but the main rule of life-skills and lifelong learning.

Conclusion

Artificial intelligence is a game-changing technology for any industry. As the technology matures and costs drop, AI is becoming more accessible for companies. Education systems that are responsive to labour market demands will incorporate AI both in the way the TVET system operates and in the education and training provided to students. Changes in practice are needed to prepare students not only for the current labour markets, but also for future disruptions. AI is now an augmentation to human work and nothing can be a substitute of human intelligence and the ability to adapt to unexpected changes.

Recommendations

1. TVET providers should seek to engage as drivers of AI innovation as well as suppliers of talent.
2. TVET institutions should begin planning and commencement of AI programmes towards workforce upgrade for the new economy.
3. Higher institutions should invest now in AI and commence teacher training in TVET.

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