Chapter 7

Developing Critical Workplace Skills through Education in Africa: The Case of Industry 4.0 Revolution

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Introduction

This chapter aims to explore and discuss substantial changes in critical skills development and education systems for I4R (Industry 4.0 Revolution) in Africa, and to equate different educational approaches evolving in connection with education in Africa. Methodologically, the chapter follows a qualitative approach to synthesise literature to answer questions like, 'How can African nations respond to I4R, or will they remain behind as it was the case with the first three industrial revolutions?' 'Are Africa's education systems ready to produce human capital for I4R?' Finally, 'How can organisations leverage the power of I4R to tackle today's challenges such as the Covid-19 pandemic, internationalisation, and globalisation?' The chapter offers an evaluative viewpoint on the diverse innovative responses evolving in Africa's education systems and in curriculum development for sustainable development to address challenges of I4R. The chapter provides twofold implications on how education in Africa may act both as a source of competitive advantage for African nations and an enhancement of their commitment to industrialisation. This chapter further fills a literature gap regarding how education policymakers can take advantage of their youthful population and opportunities to create an innovative society for I4R and beyond.

In the discussions below, this chapter will cover the following themes: The historical development of IRs (industrial revolutions) in the context of Africa *vis-à-vis* the world; education in Africa; post-I3R (Industry 3.0 Revolution); careers and skills shift in the context of I4R; concept and definitions of I4R; demand driven skill sets for I4R; the role of education in developing critical skills in Africa for I4R; and the future of Africa in I4R. The chapter also highlights challenges such as Covid-19 and how educational organisations can harness the power of I4R for human capital capacity building to tackle current challenges facing the continent.

Historical Development of Industry 4.0 Revolution

Historically, the IR started in the West around the 16th century when there was a demand for industrially manufactured goods. Following the first three IRs, I4R is characterised by digital transformation, the IoT (internet of things), DA (data analytics), AI (artificial intelligence), CPS (cyber-physical space), IoS (internet of services), AM (additive manufacturing), and CC (cloud computing) respectively. I4R is to become a reality in the next decade (cf. Fig. 1). The political debate about the term 'I4R' focuses on both the important and abstract objectives. For its promoters, I4R is not only about improving Germany's international competitiveness, but is also regarded as a tool for tackling the most pressing global challenges such as the consumption of renewable and non-renewable resources, as well as specific national challenges like the labour supply that is changing due to demographic shifts. I4R is focused on smart production, consisting of smart products, procedures, and processes. A key element of I4R is therefore the smart factory/manufacturing (cf. Fig. 1). In addition to the foregoing challenges, I4R can help to tackle emerging issues such as the Covid-19 pandemic, internationalisation, and globalisation of both skills and knowledge through 5G (fifth generation), AI, and BDA (big data analytics), to mention a few.

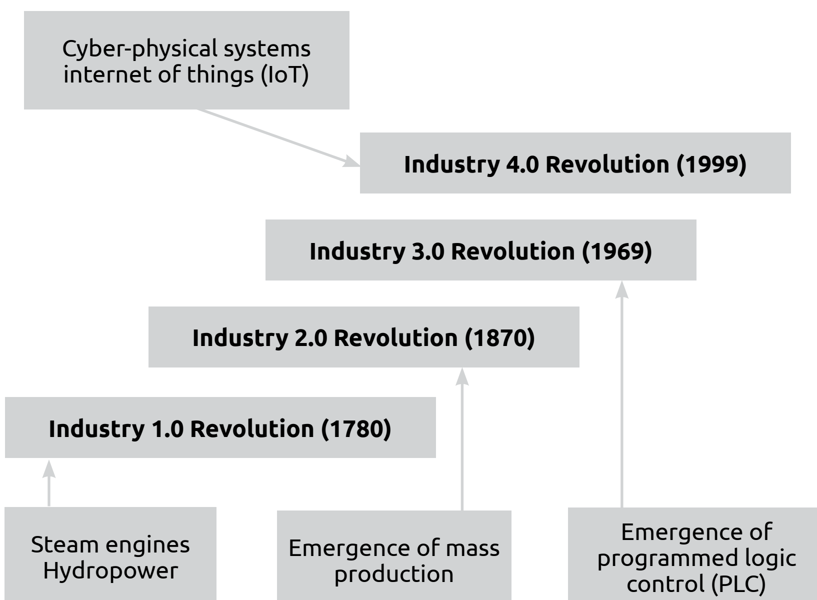


Figure 1: Chronology of Industrial 4.0 Revolution. Source: Personal archive

The first three IRs led to the change of paradigms in the domain of manufacturing: Mechanisation through water and steam power, mass production in assembly lines, and automation, using IT (information technology). I1R (Industry 1 Revolution) began around the 1780s with the introduction of water and steam power which helped in mechanical production and improved the agriculture sector greatly (Liao, Deschamps, Loures, & Ramos 2017).

Industry 2.0 Revolution

I2R (Industry 2.0 Revolution) is defined as the period in which mass production was introduced as the primary means to production in general. The mass production of steel helped to introduce railways to the industrial system, which consequently contributed to mass production at large (Liao *et al*. 2017).

Industry 3.0 Revolution

During the 20th century, I3R (Industry 3.0 Revolution) emerged with the advent of the digital revolution which is more familiar with the digital environment than I1R and I2R, as most people living today are familiar with industries, and leaning on digital technologies in production. Perhaps I3R was and still is a direct result of the huge development in computers and ICT (information and communication technology) industries for many countries (Liao *et al*. 2017). In Germany, the term 'Industrie 4.0' was brought about in 2011 to strengthen the country's industry (Ghobakhloo 2018; Veile, Kiel, Müller, & Voigt 2019). The German government funded the initiative as the backbone of its strategy to digitise the industry. The German's philosophy behind I4R is that 'manufacturing systems are vertically networked with business processes within factories and enterprises. Industry 4.0 Revolution has brought change to many professions' (Agolla 2018; Ardichvili, Zavyalova, & Minina 2012).

People have always been obligated to learn new everyday tasks, but now they are also compelled to use hi-tech gadgets, which are fast becoming the most important factor in their working lives. For example, the emergence of the pandemic in 2019 caught the world by surprise, causing disruptions such as the shutdown of the world's economies and operations. Big parts of the world immediately adopted social distancing and working remotely. This created challenges to both workers and academics (including students), as the new normal demanded immediate applications of the IoT, such as BDA, and VR (virtual reality) to continue with their businesses. In hurried manner, both workers and academics were required to adjust, hence, to start using the features of I4R. The rate at which this new normal was being implemented, did not match the skills and knowledge available to enable the smooth implementation of these features, given that most workers and academics were technologically incapable to adopt these features. However, the one notable thing is the increased H2M (human-to-machine) or H2T (human-to-technology) interactions which have never been witnessed before the emergence of the pandemic. I4R is being presented as an overall change by the digitalisation and automation of every part of the organisation, as well as the manufacturing process (Schwab 2016). Big international companies that use concepts of continuous improvement and have high standards for research and development will accept the concept of I4R and make themselves even more competitive in the market.

Concept and Definitions of Industry 4.0 Revolution

The I4R concept must encompass not only value creation *per se*, but also work organisation, business models, and downstream services. It does this by using IT to link up production, marketing, and logistics and thereby capture all resources, production facilities, and warehousing systems (Matthias, Fouweather, Gregory, & Vernon 2015; Chuang & Graham 2018). The re-organisation thus extends from the energy supply and smart power grids to advanced mobility concepts which are smart mobility and smart logistics. On the technical side, the concept is based on integrating cyber-physical systems into production and logistics, and the rigorous end-to-end implementation of the IoT and services in industrial processes (Mrugalska & Wyrwicka 2017). In this smart environment, the concept of the IoT and services that were already devised a decade ago, will now become a reality. This process involves developing people and capital mobility, changing modes of production, consumption, learning, working and leisure, and increasing worldwide competition (Migliore 2015; Murawski & Bick 2017). The three major components contributing to individual or small team creativity are expertise, creative thinking skills, and intrinsic motivation (Collet, Hine, & Du Plessis 2015; Ibrahim, Boerhannoeddin, & Bakare 2017; Karakas & Manisaligil 2012). While there is evidence of formal education systems in the Western world during I1R, there is no mention that such formal education did happen on the African continent. However, this does not mean that the African continent never had any form of education. A lack of documentation about events and activities taking place in the society, contributed to this missing link.

Definitions of Industry 4.0 Revolution

Kagermann, Wahlster, and Helbig (2013) define I4R as 'utilising the power of communications technology and innovative inventions to boost the development of the manufacturing industry.' I4R encourages the manufacturing efficiency by collecting data smartly, making correct decisions and executing decisions without any doubts. For example, BDA is useful in executing business decision-making, particularly in the prediction and tracking of both students' intentions to drop out and their performances. This simply means that an over-relying on human beings for data collection, storage, and analysis is minimised if not eliminated, hence improving the pace at which the decisions are fed into the operations (Becker, Burghart, Nazemi, Ndjiki-Nya, Riegel, Schäfer, & Wissmann 2014). By using the most advanced technologies, the procedures of collecting and interpreting data will be easier. The interoperable operating ability acts as a 'connecting bridge' to provide a reliable manufacturing environment in I4R (Heng 2014). This overall consciousness gives I4R the most important aspect of AI functions (Qin, Liu, & Grosvenor 2016). I4R is surrounded by a huge network of advanced technologies across the value-chain. Service, automation, AI, robotics, IoT, and additive manufacturing are bringing in a brand-new era of manufacturing processes. The boundaries between the real world and virtual reality are getting blurrier and causing a phenomenon known as CPPS (cyber-physical production system) (Schumacher, Erol, & Sihn 2016).

I4R makes full use of emerging technologies and the rapid development of machines and tools to cope with global challenges to improve industry levels. The main concept of I4R is to utilise advanced IT to deploy IoT services (Becker *et al*. 2014). Production can run faster and more smoothly with minimum downtime by integrating engineering knowledge. Therefore, the product, which is to be built, will be of better quality, while production systems are more efficient, easier to maintain, and more cost effective. I4R is differentiated by a few characteristics of new technologies, for example physical, digital, and biological worlds (Mohamad, Sukarma, Mohamad, Salleh, Rahman, Rahman, & Sulaiman 2018). The improvement in technologies is bringing significant effects on the development plans of industries, economies, and governments. Schwab points out that I4R is one of the most important concepts in the development of the global industry and the world economy (Schwab 2016).

The modern and more sophisticated machines and tools with advanced software and networked sensors can be used to plan, predict, adjust, and control the societal outcome and business models to create another phase of value-chain organisation and it can be managed throughout the whole cycle of a product. Thus, I4R is an advantage to stay competitive in any industry. To create a more dynamic flow of production, the optimisation of the value-chain must be autonomously controlled (Mrugalska & Wyrwicka 2017). For example, BDA improves the productivity of education, using its technology all over the levels of the education system, at teaching, retention, administration, and reporting (Bamiah, Brohi, & Rad 2018). It facilitates the outlook and effectiveness of education by enabling the extraction of insights from learning experiences, tracking learners' learning processes and progress, besides ensuring their retention (Bamiah *et al*. 2018). However, despite these benefits, there are still some challenges that hinder its full implementation, particularly in Africa. The complexity of architecting big data, especially with legacy educational systems and the shortage of experts, besides the security, privacy, and ethics issues, should be considered when implementing BDA in education (Bamiah *et al*. 2018).

Features of Industry 4.0 Revolution

I4R has created a new economy, called the *Gig economy model*, which is also known as *shared economy*, being hinged on digital platforms and AI. This has created chaos in the traditional understanding of employment relationships and career sustainability in manufacturing. Typical features/characteristics of I4R and its application workplace are as follows:

- BDA: This is the utilisation of digital technology to conduct analysis. It can be used in student performance tracking, extracurricular interactions, and results of social behaviour by creating a profile that can be mapped with student profiles from the institution's network, to suggest the most relevant major faculty courses (Muhammad, Tasmin, & Aziati 2020). In addition, improved decision-making, and resource management, as well as the success rate of students can be increased by identifying risks at an earlier stage (Tulasi 2013). Similarly in healthcare, BDA can be applied to predict viral diseases such as Covid-19 before spreading, based on a live analysis. This can be identified by analysing the social logs of the patients suffering from a disease in a particular geo-location. It assists the healthcare professionals to advise the victims by taking necessary preventive measures (Archenaa & Anita 2015).
- SIMULATION: Simulations are done by using RTD (real-time data) to represent the real world in a simulation model, which includes humans, products, and machines.
- IoS: IoS acts as 'service vendor' to provide services through the internet according to the types of digitalisation services. In short, IoS is concerned with and makes use of the internet for new ways of value creation through the materialisation of a PaaS (product-as-a-service) business model (Chawlaa, Angrab, Suric, & Kalrac 2020). The process directly links the producers with the customers, hence resulting in reduced time for the services to reach the customers. Using the faster internet connectivity based on a superhighway such as 5G (fifth-generation) communication networks, customers are assured of faster service deliveries (Chawlaa *et al*. 2020). The premise of IoS is to create seamless direct links between the manufacturers of consumer products with the consumers, and to strengthen their competitive position by offering supplementary services and cultivating additional sources of revenue, based on a technological infrastructure which is provided by IoS (Becker *et al*. 2014; Ghobakhloo 2018).

- AR (AUGMENTED REALITY): This technology can bring huge support for maintenance works in business due to reduced time needed for maintenance works and a reduction of potential errors in maintenance works (Becker *et al*. 2014). It can predict with high accuracy and allows the frequency of maintenance to be kept at low numbers by utilising predictive maintenance to prevent any unplanned reactive maintenance.
- CPS: Each production system of CPS has sensors installed in all the physical aspects to connect the physical things with virtual models (Tay, Lee, Hamid, & Ahmad 2018).
- AM: I4R is stimulating the utilisation of advanced data technologies and smart production systems. Hence, AM is one of the crucial tools to embrace I4R.
- IoT: It can provide an advanced connectivity of systems, services, and physical objects, enabling object-to-object communication and data sharing. IoT is a network of physical objects, machines, people, and other devices that enables connectivity and communications to exchange data for intelligent applications and services (Schallock, Rybski, Jochem, & Kohl 2018). These devices consist of smartphones, tablets, consumer electronics, vehicles, wearables, and sensors that are capable of IoT communication (West 2016). The world is already referring to 5G networks that are capable of faster communication. IoT is characterised by devices such as 5G communication networks that can enable one to download an interactive 3D (three dimensional) video in a few seconds, a smart home which anticipates your needs, while autonomous vehicles take you safely to your destination (West 2016). All these gadgets are already being tried and tested, and it is envisaged that countries such as Sweden, Germany, Finland, Japan, China, the US, and many others will have driverless cars by the year 2030. This world of 5G broadband technology promises speeds of more than 100 megabits per second, more data bandwidth, and fewer delays due to built-in computing intelligence that handles data very efficiently (West 2016). This will result in bringing together improved connectivity, cloud-based storage, and an array of connected devices and services (West 2016). Advanced digital networks will bring together a system that connects billions of devices and sensors, enabling advances in health care, education, resource management, transportation, agriculture, and many other areas (West 2016).
- CC: This is a (new) system logic that provides a huge space of storage for the users. In CC, the storage of information is limitless, as this provides a huge space for storing vast and large data in a retrievable state for easier use by the end users, hence, eliminating an over-reliance on physical storages that was synonymous with the past three IR phases (Wilkesmann & Wilkesmann 2018). Such developments eliminate risks associated with

storages namely missing documents, hard copy files, costs associated with storage spaces, and many others. It also eliminates all sorts of physical spaces that have been the characteristics of the three previous IRs (Becker *et al*. 2014; Chawlaa *et al*. 2020; Mrugalska & Wyrwicka 2017). In terms of workplace skills and competencies which will be needed in I4R, there seems to be a unanimous understanding that some shifts demand unique sets of skills that may be differentiated with current ones (Raul, Katz, Koutroumpis, & Callorda 2013). Such skills are not similar to someone with skills, competencies, and knowledge of record keeping, but rather someone with technical skills in CC.

- AUTONOMOUS ROBOTS: Today's robots are more flexible and advanced in their operations and functions, in addition to being easier to operate in multitudes of fields. These robots can interact with each other through collaborative networks, while at the same time being able to have a real-time interface with humans under the guidance of handlers (Raul *et al*. 2013). The implication is that employees working in line assemblies and manufacturing need to be reskilled and retooled to remain relevant in the job market, or completely become jobless as most of the work will be carried out by the robots (Teng, Ma, Pahlevansharif, & Turner 2019).

The smart factory controls the fast-growing complexity while also boosting production efficiency. In the smart factory, there is direct communication between human, machine, and resources (Iyer 2018). Smart products know their manufacturing process and future application (Rowe 2019). With this knowledge it actively supports the production process and the documentation ('When was I made?' 'Which parameters am I to be given?' and 'Where am I supposed to be delivered?'). With its interfaces to smart mobility, smart logistics, and smart grids, the smart factory is an important element of future smart infrastructures. Conventional value chains will thereby be refined, and totally new business models will become established (Agostini & Filippini 2019). With all these in mind, and the obvious fact that workplace characteristics have changed – hence the skills sets too – human beings will have to interact with robots and communicate to produce goods and services that were formally traditionally reliant on mechanically production processes (Rowe 2019).

The main features of I4R lead us to pose one question: 'What should the skills and knowledge be like in I4R?' In the following section, we discuss some of the skills and knowledge found to be very relevant.

Critical Skills for Industry 4.0 Revolution

Globally, the world is going through a series of fast transitions due to the digitalisation automation of economies propelled by I4R. Many of the challenges that are being addressed because of I4R skills, are Covid-19 associated issues that shifted learning and working to remote learning and working. Globalisation has created a window of opportunity and challenges the world on how education is worldwide being offered to students. Due to globalisation, any education system must offer leaners knowledge and skills that make them fit well into a diverse work environment other than that of their original country of domicile. For example, Japanese education providers, with their headquartered in Tokyo, using the power of I4R, specifically VR, can now have classes going on simultaneously in over five different continents with multiple students having connections to the lecturer in Japan. This creates an interactive platform where students from different continents and their lecturers communicate effectively just like in physical face-to-face lectures. Now educational institutions are using I4R features such as VR in the form of virtual classes to reach out to millions of students across the globe. This has reduced the costs and expenses that were formerly associated with travelling to the place where such learning takes place, as education can be provided seamlessly to students anywhere and anytime. All these features of I4R have become a reality with the onset of Covid-19.

For example, due to the pandemic, many educational institutions around the world were forced to adopt key features of I4R such as VR and BDA to continue providing classes to their students. The pandemic converted the centuries-old face-to-face teaching paradigm into a technology-driven one (Rizvi & Nabi 2021). Educational institutions quickly adopted some form of ODL (open and distance learning) practices, which would not be possible without the application of I4R technologies (Hall, Connolly, Grádaigh, Burden, Kearney, Schuck, Bottema, Cazemier, Hustinx, Evens, Koenraad, Makridou, & Kosmas 2020). The advancement of, and innovations in technology have affected different fields of our daily life, including methods adopted for education and trainings (Kant, Prasad, & Anjali 2021). Technology has transformed how ODL could currently be offered to students. Many institutions offering ODL have embraced most of the I4R features such as VR and DA to reach out to students. Features that have found usage in ODL are digital initiatives, the production of SLMs (e-materials/e-speech learning models), the design of MOOCs (massive open online courses), OERs (open educational resources), LMSs (learning management systems), and the evaluation of learning materials which have been included in the training curricula. I4R provides arrays of opportunities to not only ODL institutions, but even conventional ones, as it quickly adopted the digitalisation of education due to Covid-19, to better serve the educational needs of more varied students. I4R can be utilised to optimally harness the basket of technological advancements which opens a plethora of more recent possibilities (Kant *et al*. 2021).

ODL has transformed itself from correspondence to *virtual* learning, where students can access education through various platforms. However, the quality of the learning heavily depends on digital access levels and accessibility (Rizvi & Nabi 2021). I4R has not only transformed the way ODL is being offered to students, but the conventional systems due to the pandemic have equally changed. It is currently estimated that 60 percent of the world's student population is online. In most countries today, specifically the developed world, virtual classes on personal tablets have become standard, while many developing countries still rely on lessons and assignments sent via WhatsApp or e-mail. While this could be afforded by many students both in the developed and developing world, there are still many other students who are left out due to several factors such as internet connectivity and finances, among others.

These transitions have not only challenged the way in which humans interact with their environment, but it has also created what we may call, a *Gig economy* (Rowe, Moss, Moore, & Perrin 2017). The Gig economy, simply put, refers to a 'shared economy,' which is characterised by digital platforms, as well as AI, BDA, CPS, and DA, which are typical of the I4R environment (Chawlaa *et al*. 2017). In the Gig economy, the world witnesses more flexibilities and opportunities for workers to take control of their work-life balance. Here we refer to Covid-19 that has forced employers to provide their workers with an alternative of working from the comfort of their homes (Becker *et al*. 2014). This has resulted in a reduction of costs associated with travelling to and from workplaces, as workers could take care of their homes without necessarily engaging the services of home caretakers. While this could be viewed as positive, a side effect that could have a profound impact, is the social isolation of the workers.

Historically, the pandemic started around November 2019 and became global during February 2020. Whereas it was first identified in Wuhan (China), its origin is still unknown. The world education systems have been impacted by this pandemic, imposing formidable challenges, and creating a discontinuity of operations. To effectively respond to this impact, many ordinary workplaces and education systems were hurriedly transformed to digitalised learning systems to mitigate the effects of the pandemic. For example, modern machines could be used not only in educational institutions, but also in the medicine field to plan, predict, and control the effects of the pandemic. Another example of I4R is the simulation using RTD to represent the real world.

The development of computerised learning modules enables the assessment of students in systematic, real-time ways. Data mining and data analytic software can provide immediate feedback to students and educators about academic performance (West 2012). In health, with reference to

Covid-19, I4R features such as BDA are vital in discovering valuable decisions by understanding the data patterns and the relation between them with the assistance of machine learning algorithms (Archenaa & Anita 2015). That approach can analyse underlying patterns to predict student outcomes such as dropping out, needing extra help, or being capable of more demanding assignments. It can also identify pedagogic approaches that seem to be most effective with students (West 2012). For example, an online high school curriculum known as *Connected Chemistry* helps students to learn key concepts in molecular theory and gasses. Chemistry is made up of many elements which interact in complex ways to form chemical systems (West 2012). The programme helps learners to understand how sub-microscopic particles relate to macroscopic phenomena. The employment of this software allows educators to mine learning patterns to see how students master chemistry, statistics, experimental designs, and key mathematical principles. They do this through embedded assessment tools as well as pre- and post-test evaluations (West 2012). The results indicate that students go through steps in developing mathematical models of complex chemical processes. In relating the volume and pressure of gases, educators found that half of the students were not able to use maths to summarise key relations and measure how different volume levels affected gas pressure (West 2012).

In summary, we learn that I4R did not only provide us with characteristics that are applicable to the manufacturing sector, but also with the new workplace environment features, which are demanding in terms of digital knowledge and skills, creativity, creative thinking, analytical thinking, and numerical competencies as opposed to the previous three revolutions (Ajagunna, Pinnock, Johnson, & Teare 2018). For example, as discussed above, Covid-19 has disrupted many aspects of human life, such as employment prospects, economic prosperity, education, business, social life in the form of social distancing, as well as personal and professional relationships (Salam & Bajaba 2021). World connectivity was disrupted as different countries imposed travel bans and shut their boarders.

Several skills and knowledge sets have been added to the traditional skills domain to address the skills gap between I4R and the past three IRs (Moon 2018). In Table 1 below, such skills and knowledge have been divided into two domains, namely technical and non-technical (soft) skills. Specific research studies have summarised the skills needed by today's workers to fit well into I4R (cf. Maisiri, Darwish, & Van Dyk 2019).

Table 1: Industry 4.0 Revolution Skills

Skills category	Sub-skills set	Skills set
Technical skills	Technological skills	Designing skills that incorporate virtualising, simulating, interoperability, modularising, and decentralising capabilities. Fault and error skills. Application and use of technological skills. Process digitalisation and understanding. Ability to work with the IoT, autonomous robots, 3D printing, and other advanced technologies. Interaction with modern interfaces.
	Programming skills	Computational skills. Simulation skills. Coding. Computer and software programming skills. Software development.
	Digital skills	DA/data processing. IT/data/cyber security. CC skills. IT knowledge and abilities. AI skills. Digital content creation skills.
Non-technical skills	Thinking skills	Creativity, innovation, practical ingenuity. Critical and logical thinking. Flexibility. Complex problem solving and troubleshooting. Analytical thinking skills. Technical and literate communication. Collaboration (including machine-human skills). Interdisciplinary skills.
	Soft skills	Teamwork. Perspective-taking. Professional ethics. Understanding of diversity. Self-awareness, self-organisation. Interpersonal skills. Intercultural skills.

Skills category	Sub-skills set	Skills set
	Personal skills	Social responsibility and accountability. Lifelong learning skills. Leadership skills/people management. Emotional intelligence. Negotiation skills. Entrepreneurship. Adaptability.

Source: Reproduced with permission from Maisiri *et al*. (2019:99).

Education in Africa for Industry 4.0 Revolution

In the foregoing sections, we will discuss the concept, the main features/characteristics of I4R, and how it has changed the world of work in terms of skills, competencies, and knowledge that employers will require for job applicants to have (Rowe 2019; Teng *et al*. 2019). During I1R, Africa as a continent was a land mass without independent states as it is today. It was therefore one large mass of land occupied by people who were using crude forms of production as means to achieve their socio-economic goals (Chhetri, Gekara, Manzoni, & Montague 2018; Cotsomitis 2018). This trend continued until late I2R. During this period, Africa provided raw materials to the world, propelling the three stages of the Western industrial revolutions and civilisation. From I3R onward, African countries were gaining their independence from their colonial masters, hence most of the education systems were either not in place or effective to propel the continent to industrialisation (Maisiri *et al*. 2019).

Africa is rich in natural resources. However, this continent does not seem to be intellectually rich enough to enable it to utilise its vast resources for both domestic and international prosperity. In Figure 1, the study has demonstrated the chronological order of the evolution of the IRs, with each stage indicating various technological discoveries and inventions (Mubarak, Suomi, & Kantola 2020). Of interest is that very little of these developments are attributable to the continent. However, with I4R, Africa is expected to claim its rightful place by becoming a force in terms of technological advancement in all spheres of its activities. Africa is well endowed with youthful people as well as natural resources, things which are very critical for the success of I4R. in 2021, the Africa population stood at approximately 1.4 billion people of which the average/median age was 19.7, based on the UN (United Nations) estimates (ECA 2021). With these numbers, Africa can produce and consume what its manufactures want to, without necessarily seeking external markets. However, this would require huge investments in real-time efficient infrastructural networks within the continent to allow for the smooth flow of services, goods, and people.

Education has been and will remain the main determinant of the nations' competitiveness. As nations usher in I4R, the first two questions that come to mind are, 'To what extent is the education curriculum provider ready to embrace both gains and challenges brought about by I4R?' and, 'To what extent do African countries leverage their education system to harness their intellectual capital for I4R?' I4R is changing the way the society thinks about and transacts businesses. Historically, the term 'ESD' (education for sustainable development) was first coined at the Johannesburg Summit in South Africa in September 2002. Later that same year, the UN General Assembly passed a resolution proclaiming the period of 2005 to 2014 to be the UN decade of sustainable development. With the global challenge of literacy eventually and effectively being addressed, it is important that literacy is incorporated into the global and national Covid-19 pandemic responses and recovery plans for students of all ages (Rizvi & Nabi 2021). There is a need to ensure a learning continuity, increased access, and strengthened national lifelong learning programmes and capacities.

The conceived ESD had five tenets:

- Education that allows students to acquire the skills, capacities, values, and knowledge required to ensure sustainable development;
- education that is dispensed at all levels and in all social contexts (family, school, workplace, and community);
- education that fosters responsible citizens and promotes democracy by allowing individuals and communities to enjoy their rights and fulfil their responsibilities;
- education based on the principles of lifelong learning; and
- education that fosters an individual's balanced development.

For these tenets to be achieved in a holistic way, the integration of various components of ESD into curricula at all levels of education and in all sectors of the society is of paramount importance. It is worth noting that when the advocates of ESD convened a meeting in Johannesburg, they were clear in their minds that ESD was to solve the problems that would confront the environment directly. As a result of this, most countries adopted environment issues in their educational curricular presentations at HE (higher education) levels.

Curriculum Innovation in Africa

The changes brought about by I4R have necessitated widespread changes in the way education and training will be conducted. As we have referred to the features/characteristics of I4R, it is evident that skills and knowledge required for jobs in the workplaces have shifted. Educational curricula are meant to shape human beings socially, economically, morally, politically, and finally to prepare them for work, a trend that is based on the notion that employers will have to impart much needed competencies on the jobs (Tait 2018). Therefore, a good curriculum is one that addresses the above tenets that would be likely to bring benefits to the society that it is meant to serve. On the one hand, innovation requires a society that is open to new things and ready to adopt changes, which foster social and economic development (Pulkka 2019).

Whereas innovation takes place almost every day in the society, it took almost a decade for education to reflect such changes in the society in the similar pace and fashion in its curricula. This has caused a gap between the curricula and the workplace requirements in terms of skills, competencies, and knowledge as well as HE systems all over the world, which are synonymous with the production of young graduates who are not capable to cope with the demands of the innovation taking place in the society (Morselli 2018; Naim & Lenka 2018), therefore creating a mismatch between job seekers and employment opportunities available in the workplace. This mismatch, if not bridged, is likely to cause structural unemployment, as most of the graduates from educational institutions may not fit well in I4R work environments (Chuang & Graham 2018). The shift in the workplaces in terms of knowledge, skills, and competencies due to I4R, will now require all educational providers to redesign their curricula, to move away from theories and be more industry-based to prepare graduates for I4R job requirements (Maisiri *et al*. 2019; Teng *et al*. 2019). This changing demands in the workplace have shifted towards a broader remit, which focuses on the attitudes and behaviours of employees, including their ability to communicate and solve problems as well as evidencing resilience at work, collectively contributing towards work readiness (Rowe 2019). HE is conceptualised, as those education providers offer vocational education or tertiary education and post-secondary certificates.

Curricula are critical in developing capable citizens, ready to undertake any assignments that require their cognitive abilities. The formal education world has evolved in line with the IRs, but not at the same pace at which technological development has evolved. To match the pace of industrial development and economic changes, curricula must be revised in similar fashion. The question here is whether IHEs (institutions of higher education) are truly able to adapt quickly enough to an increasingly uncertain and volatile market, through collaboration with employers to create future-proofed, innovative curricula with delivery models that meet learner and business needs (BCES 2014; Nguyen 2018; Rowe 2019). With the rate at which technological development and advancement take place, it would be profitable for IHEs to have a strong link with the employers in order to know how to respond to the workplace needs. Failing to have such links would just result in futility in terms of preparing graduates who are ready for jobs which are available in the markets (Witte 2014; Wolhuter, Van der Walt, & Steyn 2016). Therefore, educators should consider opening up IHEs for more interactions with industry, and more importantly to give them more scope in curriculum design and development to respond to job markets in terms of skills and knowledge.

South Africa

South Africa, just like any other developing economy has not been left behind in its quest for skills development in preparing for I4R. The country has already prioritised its human capital development needs to bridge the skills gap between education and businesses.

To transform the education practices that existed within the country up to 1994, the South African Ministry of Education decided in 1996 to adopt a new education structure, the NQF (National Qualifications Framework) and philosophy/approach (outcomes-based education). Changes in education structures are linked to the rethinking and re-examination of existing structures, philosophies, curricula, and its related components. Today, the South African education system has engaged with the 21st-century skills through the development of CAPS (Curriculum and Assessment Policy Statement), which is a single, comprehensive policy document that provides guidance for learning and teaching in South African schools. In the curricula, the embedded skills and values associated with I4R are found. The curriculum goals are to produce students that can identify and solve problems, making decisions by using critical and creative thinking, working effectively with others, critically evaluating information, communicating effectively, and showing a responsibility towards the environment and others. Apart from these skills, we find a wider government prioritisation of the promotion of inclusion, diversity, equity, and life in the I4R, which are driven by the country's historical past. The key salient features of Souths Africa's education curricula are:

- identify problems;
- solve problems and make decisions;
- critical and creative thinking;
- team players, groups, organisations, and communities;
- organise and manage effectively;
- collect, analyse, organise, and critically evaluate information;

- communicate effectively, using visual, symbolic, and/or language skills in various modes;
- use science and technology effectively and critically, showing a responsibility towards the environment and the health of others; and
- demonstrate an understanding of the world as a set of related systems by recognising that problem-solving contexts do not exist in isolation.

Moreover, in the Report of a ministerial task team on the implications of I4R for the post-school education and training system (DHET 2020:35-41), the South African government identified some of the key areas at the centre of the new vision for the PSET (post-school education and training) system to be the focus on ensuring that the programmes, courses, and other learning opportunities are aligned with the needs of I4R. They envision a PSET system that provides:

1. A strong core of education and training programmes that align with the changing needs of both the South African society and the world of work in the context of the I4R. Instead of generic and superficial curricula, PSET programmes are envisioned to provide access to specialised skills and content, grounded in disciplinary bodies of knowledge, and providing space for growing inter-disciplinary engagement. Critically, the mechanisms for reviewing and updating PSET programmes and curricula will be revised and streamlined to enable curriculum development to keep pace with the production of new knowledge, enabled by I4R requirements.
2. Access to high-quality educational opportunities that meet a burgeoning and immediate demand for 'digital skills' in the labour market created by the 4IR and a parallel need for a new wave of South African innovators and entrepreneurs who, whether from within government, in the private sector, or broader civil society, will help to drive and shape the I4R to the social and economic benefit of all its citizens.
3. Massive increases in short-course skilling opportunities for unemployed and underemployed South Africans in parallel with wider government and private-sector efforts to rapidly grow new employment opportunities for those people. In scaling up access to these skilling opportunities, the PSET system – and particularly the CET (community education and training) and TVET (technical vocational education and training) college sectors – will need to take cognisance of the reality that most people with this need are likely to have received primary and secondary schooling that have not adequately prepared them to meet the demands of further studies. Likewise, people requiring access to this kind of educational opportunity most often have an urgent need to earn a living and limited, if any,

disposable income and time to invest in long-term, fulltime educational programmes and courses.

4. A growing emphasis on integrating into PSET programmes and courses with learning opportunities that prepare people to be able to cope with accelerating change, both socially and economically, and thus that emphasise key generic skills such as problem-solving, critical thinking, advanced literacy and numeracy skills, oral and written communication skills, the capacity for ethical reasoning, and the ability to work effectively in teams, among others.

To support South Africa's effective integration in an I4R world and the leveraging of its possibilities to create a country of opportunity for all its citizens, it envisions a PSET system with the following key characteristics (DHET 2020:35-41):

1. Educational opportunities that prepare students who are capable of creative insights, collaborating in diverse social and economic sectors, and navigating through cultural differences, which will provide them with an advantage in the workplace. This will be achieved by embracing curricula that stress multi-, transdisciplinary, and cultural perspectives. PSET education geared towards the I4R will emphasise the acquisition of creative skills, interactive pedagogies, and multidisciplinary perspectives, rather than a narrow focus on the acquisition and transfer of only disciplinary content.
2. Curricula and educational programmes that are responsive to the accelerating pace of technological change. This requires at least some specialised programmes that enable students to comprehend the role and function of technologies, adapt to them, and be able to thoughtfully analyse and predict the evolution of networked systems of technology, the environment, and educational platforms and systems. More broadly, PSET curricula also need to help students develop the capacity for ethical reasoning needed to comprehend the impact of I4R technologies on people and the environment.
3. A system that creates an 'open-loop' education platform in which students can combine building a strong initial education foundation with ongoing educational and skills acquisition opportunities throughout their lives. This would allow them to re-enter PSET at specific points where their skills become outdated and of low relevance or where they wish to advance their lives or careers in response to changing circumstances. The goal of this will be to create a PSET system that is agile in being able to respond to changing educational needs across the life of a person and as the I4R evolves and transforms society.

4. Educational approaches that enable much greater flexibility in terms of how and where students access learning opportunities. This will specifically lead to a greater integration of technology into the provision of educational opportunities as appropriate, taking account of technology access inequalities. The use of technology to support teaching and learning might take different forms according to needs and curriculum contexts, but could include online learning and blended learning courses, the use of MOOCs, the integration of AI into learning delivery to create individualised learning opportunities, the use of simulation and virtual practical demonstrations, flipped classrooms, and online tutoring, among others.
5. A wider and more pervasive application of WIL (work-integrated learning) in PSET, recognising that the workplace is an essential site of learning and that it will be critical to be able to bring PSET to the workplace, given that many students may need to continue working while they study. On-the-job learning approaches offer people the opportunity to learn while they earn, and better integrate theory and practice for better learning outcomes than traditional learning approaches.
6. Accreditation systems that allow students to accumulate 'stackable micro-credentials' throughout a lifelong learning career, which they can acquire while moving in and out of the education system and the workplace and through a diverse and growing range of educational modalities enabled by both ICT and WIL. This form of accreditation will be facilitated by a flexible qualifications framework able to accredit the accumulation of micro-credits across different modalities in an open system of learning and working.
7. Modes of educational delivery that embrace the principles of open learning, as outlined in current PSET policies. Open learning is an approach to education that aims to remove all unnecessary barriers to learning while aiming to provide students with a reasonable chance of success in an education and training system, centred on their specific needs and located in multiple areas of learning. It incorporates several key principles:

   - Learning opportunities should be lifelong and should encompass both education and training.
   - The learning process should centre on the students, build on their experience, and encourage independent and critical thinking.
   - Learning provision should be flexible so that students can increasingly choose where, when, what, and how they learn, as well as the pace at which they want to learn.

- Prior learning, prior experience and demonstrated competencies should be recognised so that students are not unnecessarily barred from educational opportunities by a lack of appropriate qualifications.
- Students should be able to accumulate credits from different learning contexts.
- Providers should create the conditions for a fair chance of student success.

8. Integrated delivery models that work at district and regional levels and that enable PSET institutions in common localities to work with each other, with public and private enterprises, with social structures, with the communities they serve, and with local, district, and provincial governments to create articulated, seamless, responsive education and development opportunities.

Kenya

The new curriculum (2-6-3-3-3)[1] replaced the 32-year-old (8-4-4)[2] curriculum system. The then education cabinet secretary, Fred Matiang'i maintained that there were sufficient stakeholder consultations on the changes, adding that the launch should not be delayed. This is the second time the country is adopting a new curriculum since the 1985 change-over from the 7-4-2-3 curriculum. That model comprised seven years of primary education, four years of lower secondary, two years of upper secondary (form 5-6) and three years for a university course (Wanjala 2017). The system was phased out because it was deemed unsuitable for the changing aspirations of Kenyans and the labour market, which was slowly beginning to embrace technology. The programme focussed on academics as opposed to orienting students for employment. It also failed to cater for the critical pre-primary level of schooling for children under six years. The 8-4-4 system was adopted to seal those gaps, but the curriculum soon came under criticism for churning out school leavers suited only for white-collar jobs.

The argument has been that the curricula neglected the sectors which accelerate economic growth such as agriculture, construction, and fishing. An influx of white-collar job trainees over time created a skills imbalance in the job market, resulting in one of Kenya's biggest obstacles to development – youth unemployment, which currently stands at 40 percent. This ignited

1 It comprises of two years in pre-primary and six in primary school, then three years in upper primary, while 'Junior Secondary (grades 7, 8 and 9) and Senior Secondary Education (grades 10, 11 and 12) will each take three years' (Wanjala 2017).

2 Eight years of primary education is followed by four years of secondary and four years of tertiary education (Milligan 2017).

the desire by the government to include TVET as a key component of Vision 2030. Roughly, Kenya requires 30,000 technologists, 90,000 technicians, and over 400,000 craftsmen to attain the mega projects of Vision 2030. The new curriculum has been touted as the ultimate remedy to the limitations identified in the 8-4-4 system because it is entirely skills-based. Students will not sit examinations, but they will be evaluated through CATs (continuous assessment tests) on the skills acquired as opposed to cramming for examinations as has been the case. Experts are of the view that it will enable students to develop beyond academics and focus on how they can best use their specific talents to make a living. The needs of special needs children have also been incorporated in the curriculum, which will integrate ICT at all levels of education. This new curriculum model places emphasis on the formative years of learning where students will spend a total of eight years – two in pre-primary and six in primary schools. Subjects to be taught in lower primary are Kiswahili, English, Literacy, a mother tongue language, as well as Science, Social Studies, and agricultural activities. Upper primary includes Kiswahili, English, Mathematics, Home Science, Agriculture, Science and Technology, Creative Arts (art, craft, and music), Moral and Life Skills, and Physical and Health Education. Others are Social Studies (Citizenship, Geography, and History) with an option of a foreign language (French, German, Chinese, or Arabic). Junior secondary (grades 7, 8, and 9) and senior secondary education (grades 10, 11, and 12) each takes three years. Twelve core subjects will be taught at junior secondary: Mathematics, Kiswahili, English, Life Skills, Health Education, Social Studies, Integrated Science, Business Studies, Religious Education, Agriculture, Sports, and Physical Education. Learners at this level will also be required to take a minimum of one and a maximum of two optional subjects that suit their career choices, personalities, abilities, and interests. Home Science, foreign languages, Kenyan Sign Language, indigenous languages, Visual Arts, Performing Arts, Arabic, and Computer Science are optional at junior secondary. Learners at senior secondary (ages 15-17) will focus on three areas of specialisation depending on their skills, talents, and interests. These are Arts and Sports Science, Social Sciences, and STEM (Science, Technology, Engineering, and Mathematics). Graduates from this level will have the option to join vocational training centres or pursue university education for three years.

Rwanda

Rwanda has embarked on curriculum reform to improve its quality of education. This is a crucial step in the direction of Rwanda's ambition to 'develop a knowledge-based society and the growth of regional and global competition in the jobs market' (REB 2015). An important shift has been to move away from a knowledge-based to a competence-based curriculum and from knowledge and skills acquisition to knowledge creation and application. The aim is to develop students' independent, lifelong learning habits, appropriate skills and knowledge, and applications to real-life situations. There is a growing recognition of the potential of competence-based education, unlike traditional subject/content-based education, to develop the capabilities/competencies that are deemed essential for success in both academia and today's knowledge-based economy (Scardamalia, Bransford, Kozma, & Quellmalz 2012).

Rwanda's proposed competence-based curriculum is filled with programmes to develop generic capabilities, such as those discussed by Yeung, Ng, and Liu (2007). The competencies proposed for Rwanda's educational system include critical and problem-solving skills, creativity and innovation, research, communication in official languages, cooperation, interpersonal management and life skills, and lifelong learning. Rwanda has adopted the terms 'competence-based curriculum,' 'generic skills,' 'generic capabilities-based,' and 'competence-based education' (Ngendahayo & Askell-Williams 2016:155-165).

The Rwandan government has refocused its attention on developing and training by transforming its human capital for the socio-economic development of the people in the country through equitable access to quality education, focusing on combatting illiteracy, the promotion of science and technology, critical thinking, and positive values. The curriculum reforms have taken a different direction, which is called the CBC (competence-based curriculum), aligned with the knowledge-based economy or I4R. This is meant to provide students with independent, lifelong learning habits, appropriate skills and knowledge, and an application of real-life situations (Ngendahayo & Askell-Williams 2016).

Nigeria

Nigeria has introduced a new senior secondary education model that emphasises the skills as well as the academic development of students. The skills component of the model is being pursued through the teaching and learning of 34 vocational (trade-based) subjects developed by the NERDC (Nigerian Educational Research and Development Council) and Nigeria's agency for curriculum development. The trade subjects, which are taught together with the academic oriented school subjects, allow students to acquire specific vocational skills in at least one trade area, based on their choice. A fundamental gap was observed after five years of implementing the new education model. It revealed that, while students had learned the trades, they lacked the entrepreneurial skills and ingenuity to deploy the acquired skills for profitable economic ventures.

In 2017, the 34 trade curricula were reformed, and a new trade and entrepreneurship curriculum was introduced to provide students with practical opportunities to acquire entrepreneurial competencies alongside their trade-specific skills, by taking part in in-school, small-scale business ventures, to prepare them better for the world of work. NERDC piloted the revised curricula before attempting a full-scale introduction across the nation. The very helpful piloting stage provided the opportunity to assess the strengths and weaknesses of the curricula before full-scale nationwide implementation.

NERDC is currently taking a critical look at the entire school curriculum with the intention of making it much more responsive to the critical needs of the country. It has developed new contents, including financial literacy education and capital market studies, trafficking in person education and online safety education, that are now being infused into the existing school curriculum. These new contents aim to support Nigeria's drive for entrepreneurship and human capital development in a digitally inclined society. Additionally, NERDC is developing an education in emergency curriculum for the formal education sector to serve the needs of thousands of internally displaced school age children affected by insurgency and other forms of crises. These curricula are designed to enable children to cope mentally and emotionally, and above all, prepare them for reintegration into the formal school system.

Botswana

In its document, Curriculum Programmes, the Ministry of Education describes its primary programme as emphasising the acquisition and application of 'foundation skills, [particularly] 'communication, literacy and numeracy skills, the development of an awareness of the interrelationship between Science, Technology and Society and the acquisition of desirable skills and attributes' (Georgescu, Stabback, Jahn, Ag-Muphtah, & De Castro 2008).

Features of the BE (Basic Education) curriculum of Botswana:

- 10 years of basic education (seven lower and upper primary, plus three lower/junior secondary).
- The five clearly defined components of BE focus explicitly on the development of competencies and skills related to life and work.
- The curriculum framework contains aims that relate directly to the future of students as individuals, community members, and citizens, and address cross-cutting themes such as environmental sustainability.
- Syllabi consistently support the competencies and skills-oriented approaches of the curriculum framework.
- Industry-specific subjects like Agriculture, which are introduced in upper primary (standard 5) reflect local economic circumstances.

- Some professional subjects are available as practical options in junior secondary (standard 9-10).
- Curricula make references to ICT in support of learning.

The components of Botswana's BE are listed as follows in its curriculum framework (Georgescu *et al*. 2008:1-164):

- Foundation skills 'applicable to work situations (decision-making, problem-solving, self-presentation, teamwork, computing).'
- The vocational orientation of academic subjects (related to the real world of work and, where appropriate, applied to various jobs).
- Practical subjects to enhance students' understanding and appreciation of technology, as well as developing manipulative skills and familiarity with tools, equipment, and materials.
- A readiness for the world of work by doing specific subjects (e.g., the study of the subject Commerce).
- Structured visits to companies and simulated work or business activities.
- Career guidance to assist them in identifying their own capacities and interests as well as understanding the labour market.

The general approach of Botswana's BE curriculum is therefore very strongly focused on the development of generic life and work competencies and skills through a range of curriculum design strategies. Botswana's aims and objectives for BE are founded firmly on a base of competency and skills development within a framework of personal growth and personal and social responsibility. The subjects in the lower primary level (standards 1-4) are broad and integrated (for example, Creative and Performing Arts contain the elements of Music, Physical Education, Design, Art, and Craft), but they become increasingly more specific in the upper primary and junior secondary levels.

Key Features of Curricula For I4R

A good education system should be able to address human needs both locally and globally. Education should be regarded as the transformation of human beings for the good of the society, and this can only be achieved through well timed and designed curricula, with the aim to train global citizens (Benešová & Tupa 2017; Reimers 2020; Venkatraman, De Souza-Daw, & Kaspi 2018). Covid-19 has decisively exposed the human inability to deal with uncertainty caused by biological diseases, hence the need to have educational curricula that can foster future scientists in all fields, both locally and at international level.

As the world becomes interconnected, there is a need to harmonise education curricula in some respects to prepare global competent people (Knights, Grant, & Young 2020; Reimers 2020; Jack, Anderson, & Connolly

2014). Therefore, an examination of the selected education curricula portrays some similarities based on what each country needs as well as the global need. Table 2 summarises some of the key skills emphasised in these curricula.

Table 2: Mapping key curriculum contents into I4R skills

Country	**Curriculum Contents**	**I4R Skills**
South Africa	Emphasis on problem-solving skills, decision-making, creative thinking, interpersonal skills, communication skills, responsibility towards environment, diversity, critical evaluation of information, and the use of science and technology.	The curriculum adequately addresses both technical and non-technical skills within I4R.
Kenya	Emphasis on ICTs, science and technology, creative arts, moral and life skills, physical and health science, religious education, music, agricultural activities, business studies, sports and physical education, literacy, Kiswahili, English, with a foreign language as option (these are compulsory as from lower primary to junior secondary schools). At senior secondary level (ages 15-17), the focus is on three areas, namely arts and sports science, social sciences, and STEM. Graduates have an option of pursuing the TVET line or university. This is based on CBC.	The curriculum adequately addresses both technical and non-technical skills within I4R.
Rwanda	There is a CBC emphasis on the following: Lifelong learning habits, critical and problem-solving skills, creativity and innovation, research, communication in official languages, cooperation, interpersonal management, and life skills.	The curriculum adequately addresses some aspects of technical and non-technical skills within I4R.
Nigeria	The curriculum emphasises the following outcomes: Financial literacy education, capital market studies, trafficking in person education, online safety education, entrepreneurship, and human capital development.	The curriculum adequately addresses some aspects of technical and non-technical skills within I4R.

Country	Curriculum Contents	I4R Skills
Botswana	The curriculum emphasises communication skills, literacy, numerical skills, science, technology, society, decision-making, problem-solving, teamwork, computing, commerce, identifying students' own capacities, ICTs, agriculture, exposure to the real world of work, and creative and performing arts (outcomes-based curriculum).	The curriculum adequately addresses some aspects of technical and non-technical skills within I4R.

Source: Personal archive

Workplace Critical Skills Development

This section discusses the workplace critical skills development to which education institutions must pay attention in order to prepare the youthful population for I4R workplaces. Critical skills for I4R should not be the sole responsibility of IHEs, but rather a shared responsibility of both employers and educational providers. For example, at the workplace, Chuang and Graham (2018) state that ideally, upgrading the workforce competencies should be done in harmony with the ongoing technological changes. There is a unanimous agreement that employees are the greatest asset to organisations, therefore experts must be active in responding to the influence of technological innovations for the workplace and jobs, as well as the performance of employees, teams, and organisations (Tay *et al*. 2018). This may require practitioners to vigorously investigate the robotic workplace environment, to identify indispensable human attributes and skills, and to anticipate evolving changes in human-to-human interactions that may require applicable HRD (human resource development) initiatives (Branchet & Sanseau 2017; Chuang & Graham 2018). The competitiveness of a country depends on the workforce it possesses as well as its skills sets (Deželan, Hafner, & Melink 2014). The current world presents different competitive playgrounds, where the soft skills and technologies dominate the competitive landscape. Therefore, as Africa ushers in I4R, it will need a skilled workforce with the relevant workplace requirements as set out by digitalised economies. As such, the key important area to which all countries must pay attention is the development of these critical skills sets that will spur both the economic growth and industrialisation brought in by I4R (Fiorelli 2017; Isa 2020; Knights *et al*. 2020).

It is obvious that the types and kinds of available relevant skills, as well as a country's capable workforce will significantly influence its adoption of I4R on both micro- and macro-levels (Maisiri *et al*. 2019:91). On the one hand, the quality of skills and qualifications of the workforce will play a noticeable role in driving the innovation and competitiveness of organisations (Maisiri *et al*. 2019:91; Benešová & Tupa 2017; Mavrikios, Georgoulias, & Chryssolouris 2018), on the other, a lack of the required skills sets will result in a noticeable drop in performance and reduced competitiveness in organisations. Yet, Schallock *et al*. (2018) state that I4R is more than a technological advancement, as it should prioritise human resource development, which involves the development of the skills that will be required in the future (Schallock *et al*. 2018).

Religious Leaders

We live in a religious society, where religious dogmas are quite prevalent. However, wherever there is a need for curriculum change/revisions, the work is assigned to the experts, without necessarily involving the religious leaders. If education is to serve the society inclusively, then it is imperative that religion be part of the curriculum development. Religion influences the behaviour and thoughts of a society, hence assists in the uptake of technologies such as AI and in genetics to, for example improve cattle breeding or crops in the fields. Therefore, their involvement in the curriculum should be noted when developing curricula for I4R.

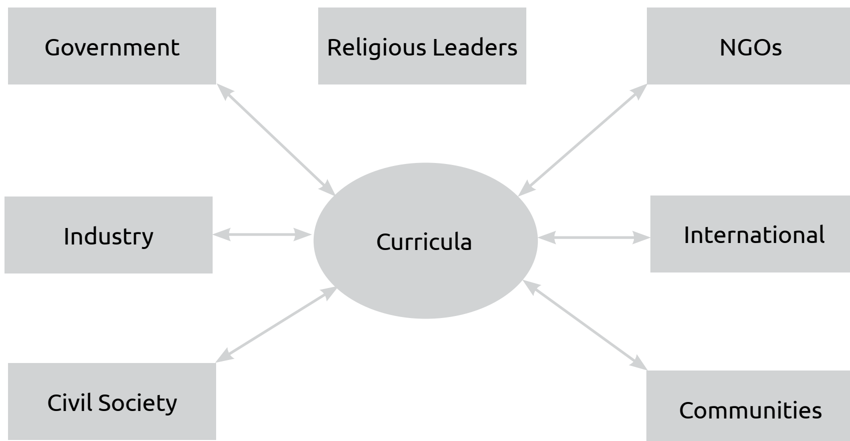
Non-Governmental Organisations

These groups are directly involved in the community activities in support of various developments. They possess first-hand information on the society's needs. Involving them will ensure that education addresses the needs of the society that is to be served. In a nutshell, education must produce what is informed by the society in general as opposed to the current situation. Figure 2 illustrates the relationships.

Industry

The industry has long been recognised as part of curriculum development, specifically with reference to tertiary education. However, its inclusion was mostly limited to just a mere consultation, where the educators had the choice of taking note of their inputs or not. However, we make a strong case for the industry being part of curriculum development, to have more voice. The industry should have a right to dictate on how curricula should be designed and when it should be revised. Education should always serve the need of the industry (Adeosun, Shittu, & Owolabi 2021; Fomunyam 2020). A failure to give them voice in curriculum development is likely to fail the very purpose for which education is supposed to serve global citizens. Global citizens need to be equipped with the right skills and knowledge to be able to work and live anywhere in the world (Fomunyam 2020). However, this can only be possible if the curricula have an international focus, while being applied locally. Figure 2 demonstrates the dualism in the relation between curricula and the industry.

Figure 2: Curricula for Industry 4.0 Revolution



Source: Personal Archive

Communities

Curriculum development has all along been concentrating on consultation with the industry, but with little input from the communities. Communities are always at the receiving end whenever there are major changes such as natural calamities – drought, famine, floods, and locust plagues, to mention but a few. Having communities' involvement in curriculum development may require that education providers design curricula that provide permanent solutions to many problems and challenges. Such involvement in development will naturally result in problem-solving skills geared towards solving the communities' problems. This relationship is demonstrated in Figure 2 above.

Civil Society

Civil society actors at both national and global levels have developed a substantive capacity and influence in a range of development issues. Partnering with them can help to contribute to the effectiveness of curricula that can address the challenges of the marginalised and vulnerable groups in the society (Naudé 2018). The success of curriculum development and participatory governance depends on both education and an active civil society with healthy levels of civil engagement. Involving the civil society in curriculum design and development can result in producing people with skills and knowledge needed for the I4R workplace. These are people who fit well within the requirements of the future workplace (cf. Fig. 2).

Government

There is no doubt that governments should play a critical role in the development of education in various facets of life. Governments provide much needed resources that act as seedbeds for education to flourish. Without the help of governments, no education will achieve its purpose or mandate. However, a government can sometimes act as a hindrance to education if the policies are not well and carefully thought through, crafted in line with changes in the society (DHET 2020:35-41 of 67). Good education systems curricula should be driving governments' present and future agendas. Therefore, in this chapter, we appeal to governments to eliminate unnecessary bureaucracies that sometimes result in out-dated curricula (Deloitte 2018). Curricula should move at the pace of the external changes brought about by societal needs through responding to such needs as shown in Figure 2 above. In the following section, the chapter proposes curricula for I4R.

International

The world has become a global village where the rate and pace at which human beings interact, either physically or through technologies, are very frequent. No country can survive in isolation – a challenge confronting one country quickly becomes a world problem, for instance, the Afghanistan case of refugees due to the Taliban war, and Wuhan's Covid-19. Education curricula cannot be designed without the benchmarking with other international communities, as education is supposed to serve humanity irrespective of its location. The involvement of other international communities in the curriculum development of one community, is paramount to enable education to add value and serve humans better. Figure 2 attempts to show the components of curricula for I4R that can be used to develop critical and knowledge-based skills for sustainable development in Africa. Whereas this involvement is vital, it is also imperative that African countries think globally, while acting locally for such curricula to be of benefit to humanity.

Future of Africa in Industry 4.0 Revolution and Beyond

The future of Africa seems to be well based on the analyses of the current education curricula. Employability in I4R will depend on how education institutions are implementing these technical and non-technical skills to students in preparation for readiness in the workplace. Identifiable skills needed for I4R across major sectors such as communication, problem-solving, decision-making, analytical and critical thinking, synthesising information, teamwork, interpersonal skills and continuous learning, numeracy, Science, Mathematics, and ICT will be the key success factors for a knowledge-based economy (Kayembe & Nel 2019). Therefore, education institutions will have to ensure that their current curriculum development addresses the following factors for I4R and beyond:

- Joint curriculum development between the education sector, civil society, communities, religious leaders, government, and private and non-governmental organisations. The emphasis should be on the cocreation of curricula, not only consultation as has been the norm when such curricula are designed. This will ensure that most of the graduates will be capable of entering the world of work, ready to be absorbed or ventured into entrepreneurship (cf. Fig. 2).
- The curriculum development must address both local and global needs, given that the world is interconnected. This will prepare graduates to be globally ready for both local and international assignments (Naudé 2018:16 of 22).
- Flexibility in the development of curricula to allow for changes, as global changes have impacts on the education systems. Most of the curriculum revisions take approximately five years, while the external changes take place every day. It would therefore be appropriate that the current curricula adapt to these changes when necessary to address the missing links in the labour markets.
- Education institutions need to move away from the traditional programmes and embrace the new imperatives such as STEM, ICT, entrepreneurship, creative and performing arts, and other life skills hinged upon students' capabilities and abilities.
- Africa has numerous natural resources and a youthful population. However, a lack of critical knowledge in exploiting these resources for the betterment of the continent has resulted in the exploitation of it by foreign organisations. Infusing subject specifics such as STEM, ICT, and life skills, will empower the youths to exploit these resources for the good of the continent.
- Curricula should be designed to suit and focus on three areas of specialisation, depending on students' skills, talents, and interests, while not ignoring Arts and Sports Science, Social Sciences, and STEM.
- The future belongs to the technology-oriented workplace; hence waiting to embrace technology until students reach senior school or tertiary levels, will be ill informed. The curricula should be designed with the future in mind, and preparing young children to embrace technology as early as kindergarten should be a must to address the future of the workplace. The

use of ICT and MOOCs will facilitate the non-discriminatory participation in developing skills required for I4R, in addition to using cyber-physical education for developing skills and building competencies of students and educators across the continent. In fact, leveraging on the power of I4R, African countries can tap into the knowledge base of most advanced countries' education without necessarily having to send students abroad.

- Strengthening TVET to cater for those students who could not gain direct entry into universities. TVET offers much-needed skills and knowledge that are critical for survival in I4R.
- Embrace smart teaching technology from the lower level of education. Such technology will not only be limited to learning and skills development in both real and virtual worlds, using AR and VR, but also integrating the IoT and AR technologies in educational institutions' laboratories to develop skills required in I4R.

Future Knowledge and Skills Development

I4R has also created a window of opportunity for education to be offered through ODL, using a variety of gadgets to prepare students for the 21st-century workplace. Such gadgets that are currently in application in providing education through both ODL and conventional education systems, particularly during Covid-19, are e-materials/e-SLMs, MOOCS, OERs, LMSs, and the evaluation of learning materials which have been included in the training curricula. Today, with the digitalisation of educational contents, students can access their learning material anywhere and anytime, hence bridging the geographical space, as the world becomes one global village through I4R. These transitions have not only challenged the human beings to interact with one another, but they have created a 'shared economy.' African countries need to develop its own human capital skills and knowledge base to be competitive at international level through the right education curricula that have an international tendency but are implemented locally. Similarly, with the I4R as background, countries and organisations can develop critical skills and knowledge for the future.

Research indicates that the global economy will have a shortage of 40 million workers with tertiary education, a shortage of 45 million workers with a secondary education, and a surplus of 95 million low-skilled workers during the third decade if the 21st century (Deloitte 2018:15). Deloitte's study found that not all these deficits and surpluses are distributed equally on a global level. For instance, China alone is expected to have a deficit of 24.5 million workers, while sub-Saharan Africa's workforce will soon reach 20 percent, double of the total global workforce it had in the early parts the second decade of the 21st century (Strack, Baier, Marchingo, & Sharda 2014). To address the challenges and demands for future jobs and skills in the I4R environment, the education sector in Africa should focus on and move away from the current traditional education systems to embrace education systems that address I4R knowledge and skills requirements. It is well recognised that I4R implications for workforce transformation and shifts in workforce will impact the future of work and education systems of nations (Adeosun *et al*. 2021).

African governments have been developing their human capital using traditional methods of the classroom, where the success of a student is judged by how well that student passes formative and summative assessments, based on the courses or syllabi taught. This approach had some gaps because it only relied on the subjects that could be taught in classrooms. However, with the shift to I4R job requirements, some knowledge and skills cannot be developed in classrooms alone. For instance, Fomunyam (2020:27) points out that the 'current curriculum used in African higher education is old, and mostly irrelevant to the demands of the I4R, and most of the contents of curriculum cannot equip students with necessary skills to perform in organisations of the future.' Fact is that the current content of curricula used in African HE does not match the current labour market demand and/or development needs. This has created a dissonance between the curricula needed and demands of employers in the I4R. To develop Africa's knowledge and skills base fit for I4R workplace requirements, proposals have been made to reconfigure education curricula to allow for students to develop capacity in the event of this rapidly emerging areas of genomic, data science, AI, robotics, and nanomaterials (cf. Fomunyam 2020:28; Penprase 2018). African education systems must inculcate the digitisation of the I4R, to ensure that employees are knowledgeable on the newly developed organisational technologies (Fomunyam 2020:28).

Therefore, Africa, given its growing young population, must develop knowledge and skills for its workforce, using excellent curricula that are fit for purpose, focusing on I4R workplace requirements. African governments must invest significantly in the knowledge base generation and workers through schooling and re-tooling, to find occupations less susceptible to automation, that expose workers to being replaced by automation due to the lack of relevant education and skills (Naudé 2018:13 of 22). In light of the foregoing debate, we propose that African governments should focus on the following key areas for future development of knowledge and skills to participate in the I4R economy:

- First, African governments must understand the advantages and disadvantages of I4R and apply its technologies and products on education to quality students who have the competencies and skills to comprehend future challenges and try to solve them. This will require the integration of disciplines such as STEM. In addition, there must be an integration between the educational system elements, namely education policy, teachers, curricula, learning environments, students, and industrial sectors in society. This will assist in preparing the future generation for I4R workplace requirements.

The educational sectors will benefit a lot from such integration of curriculum design and instructional activities that will qualify the students to have future jobs because in future, the problem could not be the lack of jobs, but rather, a shortage of skills that will depend completely on I4R ideas (Elayyan 2021:28; Deloitte 2018:22). Industry-university collaboration in curriculum development will help in eliminating mismatches in knowledge and skills with what industries need (Deloitte 2018:22). Naudé (2018:15 of 22) adds that private sectors' involvement, through for instance advice on curriculum reform, internships, on-the-job training, and (co)-funding of educational infrastructure, are some examples of the learning environment that needs to be scaled up to help develop knowledge and skills for I4R workplace requirements.

- Second, developing skills for future work is complicated and not a simple one. For instance, it is predicted that people such as engineers, programmers, doctors, waiters, etc. will lose a lot of jobs, and new jobs will emerge like robot technicians, BDA analysist, AI experts, blockchain designers, and 3D-printing engineers. However, this loss can be minimised by transforming knowledge skills to liquid or soft skills. Training and development may require that students' right brain skills be developed to have skills such as technical skills, critical thinking, coordinating with others, verbal communication skills, and time management (Elayyan 2021:28). In addition, students studying basic and applied sciences also need to understand the political and social nature of the world in which they live (Butler-Adam 2018:1 of 1). I4R borrows from a wide range of disciplines and this requires that IHEs should infuse students with different combinations of courses away from discipline specific courses in which they specialise.
- Third, training and development of educators with knowledge and skills on the applications of technology in teaching should be a priority of any government to enhance teachers' ability to implement some of the features of I4R in learning institutions. Research has found that the education sector in Africa is not fully prepared for I4R, however, by transforming knowledge and skills of educators, can assist in harnessing the potential of the anticipated I4R workplace. This will foster education for sustainable development through the application of principles of teaching and learning activities, hence transform the workplace to meet the need of I4R.

- Fourth, change in education institutions should emphasise the need to shift towards the imparting of complex, problem-solving, creative, and social skills, including management, leadership, change management, collaboration, critical thinking, curiosity and risk taking, communication, marketing, and sales, all which are required for entrepreneurship (Naudé 2018:16 of 22).
- Fifth, education-based models such as dual-education apprenticeship models seek to ease the transition between education and the workforce by providing students with on-the-job skills training while competing their formal education (Deloitte 2018:22; Naudé 2018). These models have been found to be platforms that businesses use for direct pipeline hiring with the opportunity to pre-screen candidates, lower the cost of recruit training without entering a formal employment process, and promote their corporate social responsibility objectives in the marketplace.

Conclusion

Africa faces unprecedented challenges as it grapples with the challenges and opportunities presented by the 4IR requirements. These challenges have now been thrown into sharp relief by the Covid-19 pandemic and associated socioeconomic disruptions, such as the recent credit downgrades. Within these highlighted challenges, though, lies an enormous opportunity, provided we act with purpose and intent, to redevelop our society and economy on a new basis, in ways that are just, equitable, inclusive, and sustainable. The I4R offers the continent many tools to support this redevelopment, as does the provision of high-quality education systems and relevant opportunities for Africans. For Africa to seize this opportunity, though, it will be necessary to reinvent its education systems, so it can fulfil its true potential as a vehicle for social development and wealth creation for all Africans. All these cannot be achieved through slow, incremental change. The economic headwinds which the continent faces, and the relentless pace of technological change precipitated by the I4R mean that the continent must respond in kind, with purpose and speed. To accomplish this, will require a willingness to reconsider many of the core principles and operational models on which the education system is currently based. This can be done, but will require a binding social contract from many key stakeholders in the African society.

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