Looking into Africa's Future: The Fourth Industrial Revolution and the Role of ICT Education

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Alliance for African Partnership Perspectives, Volume 1, 2021: African Universities and the COVID-19 Pandemic, pp. 107-114 (Article)

Published by Michigan State University Press
DOI: *https://doi.org/10.1353/aap.2021.0013*

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Abstract

ICT in education has been considered a luxury in developing countries, where, particularly in least developed countries, emphasis was placed more on building schools and classrooms. In 2020, the view of ICT and its role changed radically. Firstly, the COVID-19 pandemic highlighted ICT as a central tool. Secondly, the rise of the Fourth Industrial Revolution and awareness of its enormous potential placed ICT in a new light. Together, these triggers of change can be embraced in order to integrate key learning modules and lessons to form appropriate skills into curricula in developing countries. Frontier fields in science and technology must be promoted and supported especially in the education sector in Africa and the developing world in general.

Introduction

We live now in unprecedented times due to the global pandemic caused by COVID-19. The rapid spread of the virus has caught much of the world off-guard, causing a crisis that is global in nature, disrupting all socioeconomic sectors as we know them, including health, education, and transportation. This is happening at a time when we are entering a new era of knowledge. The automation of the Fourth Industrial Revolution will lead to an increasing number of jobs that require education in complex fields, such as artificial intelligence. In the developed world, most education was able to continue online thanks to access to information-technology infrastructure, such as broadband connectivity at home and computer ownership. However, in most of the developing world, and in least developed countries (LDCs) specifically (thirty-three of forty-six LDCs are in Africa), this has not been the case. This period of disruption from COVID-19 has laid bare inequalities in access to education, scientific literacy, deficiencies in remote learning, and the cost of the digital divide.

Romain Murenzi, Max Paoli, Sena Galazzi, and Sean Treacy, "Looking into Africa's Future: The Fourth Industrial Revolution and the Role of ICT Education," in "African Universities and the COVID-19 Pandemic," special issue, *Alliance for African Partnership Perspectives* (2021): 107-116.

Published by Alliance for African Partnership, Michigan State University.

The year 2020, and most likely 2021 as well, will be lost years for learning, with fifty-one out of fifty-four African countries deeply affected. The impact that this period of disruption in education will have in working towards the principle of "leaving no one behind," a key tenet of the 2030 agenda, is yet to be fully understood.

In this article, we will discuss areas that require focus for the developing world, and Africa in particular, to become better-equipped for a post-COVID-19 world. In this case, better equipped means having innovative learning mechanisms and STI systems, alongside resilient and environmentally friendly economies. In particular, we will discuss how countries in the developing world can become better equipped by focusing on the following areas: (1) capacity building in science and technology; (2) scientific knowledge and preparedness; (3) science literacy; (4) restructuring school curricula; (5) integrating skills and technologies provided by the Fourth Industrial Revolution; (6) women and gender-based perspectives; and (7) international scientific cooperation in a world where a major crisis, such as COVID-19, is transnational and requires global attention.

Sustainable Development and Education Challenges

In 2015, the global community made the transition from one development agenda, the 2015 agenda supported by the millennium development goals (MDGs), to another, the 2030 agenda supported by the sustainable development goals (SDGs), which will run to 2030 (Sachs 2015). These agendas respect the need to link development and sustainability, as well as the need to account for the livelihood of future generations. The 2030 development agenda provides a comprehensive plan made up of seventeen goals for national and global socioeconomic development. The agenda reflects the urgent need to protect our planet. A greater investment in education at all levels is required to achieve these goals, as well as investment in science, technology, and innovation (STI). Such investments are required not only for economic growth, but also social inclusion, which is the eradication of poverty and extreme poverty through access to food, safe drinking water, and sanitation.

The sustainable goals triangle (Munasinghe 2007) illustrates how the interplay among economic development, social inclusion, the environment, and the impact on the environment are linked to all seventeen goals. And although all of the goals are important, Goal 4, "Quality Education,'' plays a central role. It states that: "Education is not only a fundamental human right. It is an enabling right with direct impact on the realization of all other human rights. It is a global common good and a primary driver of progress across all 17 SDGs as a bedrock of just, equal, inclusive and peaceful societies. When education systems collapse, peace, prosperous and productive societies cannot be sustained" (UNESCO 2020).

Science and technology, and related investments, will be of paramount importance in achieving the SDGs. Most of the world's poor live in the Global South, sub-Saharan Africa and South Asia, especially. On the other hand, some countries in the Global South, such as Brazil, China, India, South Africa, Mexico, and Turkey, have made tremendous advances in economic development, but with heavy environmental costs. They are now called "emerging economies." They have also made tremendous advances in science and technology, and they could be tremendously valuable guiding and supporting other developing nations, notably LDCs, in their

paths forward. An important way the SDGs will help is providing a framework for improving South–South collaboration so that the poorer and less scientifically advanced countries can learn from the emerging economies of the developing world. TWAS's South–South fellowship program, which hosts fellowships at top science and technology centers in the developing world, reflects the potential and the power of this collaboration. This type of collaboration helps share knowledge and experience among countries in the Global South that have similar challenges.

COVID-19 Pandemic Times

When the year 2020 began, progress on the 2030 agenda seemed more assured. However, the global pandemic caused by COVID-19 added new challenges and obstacles to achieving these goals. The world was not prepared for the rapid spread of the virus, and it has been a global struggle to respond to disruptions to all the key sectors of society, including education. In addition, societies are also trying to balance the health threat of the virus with the economic well-being of their people. This tricky balancing act has similarities to what we are familiar with when it comes to climate change (Nordhaus and Popp 1997). And in efforts to achieve this balance, nations have confined large portions of their workforces to their homes and closed primary schools, secondary schools, and universities. Thus, the pandemic has had an impact on over 60 percent of the world's students, forcing 1 billion learners in over 180 countries to adjust to an education system in a state of flux (UNESCO 2020).

Advent of a New Era of knowledge: The Fourth Industrial Revolution and Education Delivery

All these changes are taking place as we enter a new era of knowledge. The automation of the Fourth Industrial Revolution will lead to an increasing number of jobs that require education in complex fields including artificial intelligence, advanced robotics, biotechnology, new materials, and autonomous vehicles (Marr 2019). As stated by Klaus Schwab, founder and executive chairman of the World Economic Forum, "The First Industrial Revolution used water and steam power to mechanize production. The Second used electric power to create mass production. The Third used electronics and information technology to automate production. Now a Fourth Industrial Revolution is building on the Third, the digital revolution that has been occurring since the middle of the last century. It is characterized by a fusion of technologies that is blurring the lines between the physical, digital, and biological spheres" (Schwab 2016).

Of the differences in COVID-19 responses observed between scientifically advanced and developing countries, perhaps one of the most obvious has been in education delivery. In the developed world, most education was able to continue online due to access to information-technology infrastructure such as broadband connectivity at home and computer ownership. But in most developing countries, and especially in the LDCs, this has not been the case. This period of disruption from COVID-19 has laid bare inequalities in access to education, scientific literacy, deficiencies in remote learning, and the cost of the digital divide. The year 2020 has been a lost year for learning. And 2021 is likely to be similar. Considering that a key tenet of the SDG is that nobody should be left behind, the effort to assess this setback will have to be thoroughly examined and receive a robust response. The advent of the Fourth Industrial Revolution should also

spur changes in the education delivery in developing countries and going forward should become a major focus.

Why We Need Capacity Building in Science and Technology

Developing countries in general, and most nations in Africa in particular, struggle to face multiple local, regional, continental, and global issues that arise because they lack the scientific and technological know-how and needed resources. Thus, building capacity in science and technology is essential if communities in developing countries are to address the myriad concerns, ailments, and difficulties life brings (Murenzi 2011). Although the MDGs have brought about some progress and improvement in areas such as primary education, child mortality, and major diseases (e.g., AIDS and malaria in Africa), these achievements were limited and uneven. The UN 2030 Agenda recognized, with the new SDGs, that a huge amount of work and support is needed, especially for the LDCs. In Africa, a special set of context-relevant goals were developed for the 2063 Agenda for Africa with education, skills in science and technology, inclusive growth, and sustainable development being at the top of the agenda. Yet, without programs to build and strengthen capacity in African countries and LDCs, the gap between developed and developing countries will continue to widen, especially in a post-COVID era.

Science Policy and Science Literacy

Science policy for knowledge acquisition will have to be an important priority moving forward. It will be up to policymakers and science literacy advocates to reinforce science and technology teaching and resources at all levels of education: early childhood, primary, secondary education, tertiary education, and adult education with regards to science literacy more broadly. Furthermore, to encourage innovation at all levels to help stimulate economic growth, appropriate intellectual property laws (Beckerman-Rodau 2011), and entrepreneurship should be policy priorities. Primary innovations provide low-level technologies at the grassroots level, whereas secondary innovations provide mid-level technologies at the local industries, and tertiary innovations provide the physical, digital, and biological systems.

Restructuring School Curricula to Integrate the Fourth Industrial Revolution

These challenges require us to reimagine education. We must ensure that our education systems are flexible, equitable, and inclusive (Bryant et al. 2020). We must also explore new and innovative ways for physical and distance education to cohabitate. For such cohabitation to occur, we first need to provide universal access to computers. The computer will play a key role in education delivery. Computers allow access to educational materials such as e-books and downloaded lessons, as well as providing a tool through which students can attend classes through the internet. Of course, technology alone cannot provide an education, in particular where children need better functioning schools, electricity, and, most important, trained teachers (James 2009).

Nevertheless, universal access to computers will do little to cause shifts in society if there is not universal access to broadband internet. The internet is a resilient mode of education delivery, and the use of the internet is quickly becoming obligatory. The United Nations Human Rights Council took important steps in this direction in

2011 when it called access to the internet "a catalyst for the enjoyment of human rights" (United Nations 2011); yet the COVID-19 pandemic and African countries' difficulties in shifting to online learning illustrate the extreme need for more to be done. The internet has become "a key means" by which individuals can exercise their right to the freedom of opinion and expression (United Nations 1948). Of course, this must also include adequate investments in—and equitable access to—electricity. After all, continued access to electricity, both at home and in schools, is essential to all of the above.

In addition to having universal access to these tools, individuals must have the knowledge of key skills to participate in the Fourth Industrial Revolution, which can be done by introducing them into curricula throughout the developing world. This will include teaching coding and programming as early as primary school and making areas of study such as big data and data analytics, 3D printing, and machine learning and artificial intelligence mandatory in secondary school. In the digital era, educators need to expand their understanding of what it means to be literate: not replacing traditional learning but complementing it with new conceptualizations of literacy. Computer programming and digital literacy are becoming core skills and a fundamental aspect of education, starting as early as primary school. In England, computer science has been incorporated into all levels of primary and secondary education, which enables students to begin learning about coding and internet safety from the age of five (UK Department for Education 2013). In the African context, the Rwanda Coding Academy, which has the mission of training young talented and gifted Rwandans in software programming, promotes quality and excellence in coding skills, and is intended to position Rwanda as a software development hub. This work helps them achieve their vision of producing quality and excellence in software engineering workforce development (Murenzi 2006).

School systems will need to help students adapt to rapid changes in the workplace and other impacts of rapid digitization, from ethical standards and cybersecurity to the impact on health, forensics, and other parts of the economy. These changes will present further challenges, including how we manage the impact of these new technologies on future generations. For example, with increased connectivity, children can be more easily exposed to potentially harmful material, and concerns about privacy and data security also merit serious consideration.

Women and Gender-Based Perspectives

Women, as mothers and extended family, typically spend more time with children throughout early childhood, primary school, and secondary school. For this transformation of education and science to succeed, we must recognize the central role of women and allow them to take their rightful place. At the grassroots level, we will need literacy programs for women as well as initiatives for digital literacy and computer ownership. Special attention should also be paid to gender equity in the science, technology, engineering, and mathematics workforce.

International Scientific Cooperation and Global Crises

Meeting this challenge will require the combined strength and commitment of all the world's institutions with an interest in bringing about a new era of knowledge delivery. This includes science academies; the

United Nations system, including UNESCO, the World Trade Organization (WTO), the International Telecommunication Union (ITU), and UNICEF; corporations; civil society organizations; and the UNESCO Global Alliance for Education. Education in itself is already a well-known challenge in Africa. In the primary education sector, nearly forty of the fifty-four countries in the continent have teacher-to-student ratios worse than 1:30, suffering associated consequences given the crucial role of teaching and learning in primary education.

The COVID-19 pandemic has exacerbated the education gap between developed and LDCs because of the "digital divide," which has been particularly evident in Africa. This is not surprising given the issue of electricity supply throughout the continent. According to the International Energy Agency (IEA), in 2030, over half a billion people on the continent will still lack access to electricity (IEA 2020). Regardless of where the energy will come from, it is an essential tool for education and development, in particular for growth in the digital sector. There is already a huge interest and fertile intellectual soil for the Fourth Industrial Revolution in Africa, as demonstrated by a striking number of initiatives. For example, an event in 2015 kicked off the growing network and online resources Data Science Africa (www.datascienceafrica.org). The World Academy of Sciences (TWAS) also supported its Young Affiliates with a thematic international workshop in 2019 on big data and data analytics (Treacy 2019), with a further event the same year with the Science Forum South Africa, and then another workshop in 2020. These initiatives illustrate that the digital divide that has emerged in 2020 is dangerously compromising education and development across entire sectors in Africa. As Mutiso and Hill (2020) discussed in an article published in *Scientific American*, there are a number of key factors defining this situation. Thus, the electricity gap needs to be addressed and developed nations should provide greater help and assistance because the lack of access to reliable energy supplies is crippling Africa's education efforts and compromising the achievement of many of the SDGs in the continent.

Conclusion

It is imperative to invest in science education, to increase access to ICT infrastructure for young people, to increase science literacy among the populace, and to strive toward gender equity in the STEM workforce. One of the great challenges for any nation, which the pandemic has made more apparent, is the need to develop its citizens' scientific awareness. Technology, after all, evolves rapidly, and in a greater scientific culture, it is necessary to provide all possible resources to train citizens to better understand their potential. Science literacy, as well as leading to a population that is passionate about scientific progress and the shared benefits of a strong education and robust research, helps any nation compete internationally. Policymakers play an important role dictating how this research will be used to not only bring about prosperity today but also a sustainable future for generations to come. Therefore, any country intending to change the livelihood of their people from one of poverty to better living conditions must make appropriate and necessary investments in education, science, technology, and innovation (Gates 2007). And they must do so with an eye towards how technology will transform our education systems and economy.

Acknowledgements

The ideas and opinions expressed in this

article are those of the authors and do not necessarily represent the views of UNESCO.

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Author Biographies

Romain Murenzi serves as the executive director of UNESCO-TWAS. Before that he served as Rwanda's minister of education, S&T, and scientific research (2001–2006) and as minister in the president's office in charge of S&T, with responsibilities including ICT (2006–2009). He became senior scholar at AAAS Center for Science Diplomacy (2009–2010), then director for the Center for the Science Technology and Sustainable Development (2010–2011). Murenzi was a physics professor at Clark Atlanta University (USA) from 1993 to 2001, and chairman of the physics department from 1999 to 2001. He holds BSc from National University of Burundi, MSc and PhD from Catholic University of Louvain in Belgium, a master of laws in IT and telecommunication laws, and an honorary doctoral degree from University of Johannesburg.

Max Paoli, BSc, hons., in biochemistry and DPhil in chemistry, worked in the area of protein structure and molecular recognition for almost 20 years. His research work took him from York, UK, to laboratories in New Zealand and the US, including the Harvard Medical School. He was also a BBSRC David Phillips Research Fellow at the University of Cambridge, UK. Max and his group solved the structures of several protein-ligand complexes and published research articles in peer-reviewed international journals. He was a course convener in Australia where he developed a lecture series on proteomics. In Cambridge, he was a tutor at St. John's College. Max Paoli works as program coordinator at The World Academy of Sciences (TWAS). In addition to overlooking the activities of the Academy, he delivers presentations on various topics related to sustainability, environmental ethics, sustainable development, and education for a sustainable future.

Sena Galazzi is associate program officer at UNESCO-TWAS, where she works across programs in scientific capacity building, science diplomacy and policy. Sena is in the final stages of her PhD in international politics at SOAS, University of London. Sena's background is in international development, law, and politics, with thematic specialization in migration, education, and human rights. Before joining UNESCO-TWAS, Sena was based for many years in Southeast Asia, most recently in Myanmar where she co-founded an organization focused on academic capacity building and access to education. There, she also designed and oversaw multi-million development programming focused on sustainable development and migration. Sena has worked in a variety of research, education, and project management roles across the UK, Myanmar, Thailand, and Malaysia.

Sean Treacy is a staff writer and editorial/publications assistant at The World Academy of Sciences (TWAS). He holds a master's degree in science writing from Johns Hopkins University, for which his thesis work focused on the relationship between medical science and alternative medicine. He also has a background of eight years in newspaper journalism, with a focus on local politics and education.