Sustainable Development and Education in the

Fourth Industrial Revolution (4IR)
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EXECUTIVE SUMMARY

There has been increasing interest in the use of Fourth Industrial Revolution (4IR) technologies, such as artificial intelligence, the Internet of Things, blockchain, robotics, data analytics and others, to help achieve the Sustainable Development Goals (SDGs). Recently, organisations such as UNESCO and the World Economic Forum have sponsored initiatives to make countries aware of the benefits of using 4IR technologies for sustainable development and to improve quality of life. Examples include two conferences organised by UNESCO in 2019: “Artificial Intelligence for Sustainable Development” and “International Conference on Artificial Intelligence and Education: Planning Education in the AI Era: Lead the Leap.” At the same time, developing countries such as South Africa, India and China are relying on 4IR technologies to achieve future prosperity.

Some individuals in the education sector are saying the 4IR is hype and are resisting the use of 4IR technologies for teaching and learning. At the same time, other sectors, such as e-commerce, business, industry, health and social media, are using 4IR technologies to provide services to citizens around the world. Why not use 4IR technologies in education for sustainable development and to help achieve the SDGs? Recent data on the achievement of the 17 SDGs show that countries are behind if they are to achieve these goals by 2030. Countries have to fast-track the achievement of the SDGs, and using 4IR technologies is a viable pathway to this end.

This report is based on a research project exploring various 4IR technologies, and the benefits and challenges of employing these technologies for global sustainable development and education. The report includes initial findings from a thematic review of 32 academic peer-reviewed journal articles from 2017 to 2019, and interviews with six international experts on the use of 4IR technologies for attaining the SDGs around the world, including in education. Findings include examples of the beneficial uses and implementation challenges of 4IR technologies for sustainable development and education. One of the important findings is that 4IR technologies must be used responsibly and to benefit people (4IR technologies for good); hence, the development of artificial intelligence, the Internet of Things, blockchain, and robotics systems will be advanced best by assembling a multidisciplinary team from areas such as computer science, education, social sciences, ethics, privacy and security. The aim is to develop an informed, collective understanding of the benefits, challenges and other issues arising from the adoption of 4IR technologies for achieving the SDGs, especially in relation to SDG4, which focuses on education. Recommendations for future projects and research initiatives are also considered. This project report is timed to guide countries in making the transition into the 4IR and in using 4IR technologies for sustainable development and education.

Previous industrial revolutions had major impacts on societies. In the past, the invention of steam power and machines significantly affected transportation and agriculture. Technologies of the 4IR are making huge differences in business and industry, and they are affecting education. The education sector must make the transition in the 4IR era, or the business sector will fill this gap. Teachers, learners and workers must become literate in the different types of 4IR technologies so they can function effectively in the 4IR and contribute to the achievement of the SDGs. They do not need to be experts in the 4IR but do require enough knowledge to protect themselves and use the technologies responsibly. As small states and developing countries move forward, they should build the infrastructure to move directly into the 4IR rather than adopting obsolete technologies. This will help them to achieve the SDGs in a reasonable time frame. Contents of this report offer tangible insights toward this end.
INTRODUCTION

The Fourth Industrial Revolution for Sustainable Development

Different sectors of society around the world are experiencing the Fourth Industrial Revolution (4IR). The 4IR is driven by the digital revolution, which combines the physical, digital and biological domains to develop systems to serve humans and to protect the environment. Some individuals in the education sector question whether the 4IR and the use of 4IR technologies (e.g., artificial intelligence, robotics, the Internet of Things [IoT], big data, smart cities, augmented reality, virtual reality, holograms, etc.) in education is hype or genuinely useful. The answer can be found by looking at how other sectors such as business, social media, manufacturing and e-commerce are using 4IR technologies. Far from being science fiction, 4IR technologies are very much a reality, including holograms and virtual interactions (Mavrikios, 2019; Pates, 2020).

Developing countries have realised the potential of the 4IR for education and for achieving the Sustainable Development Goals (SDGs). For example, South Africa recently established the Fourth Industrial Revolution – South Africa initiative (4IRSA: https://4irsa.org), and India recently established the Center for Fourth Industrial Revolution: India (C4IRIndia). Other countries in Africa are looking at implementing the 4IR to become global powerhouses (Ndung’u & Signé, 2020). Below are quotes from influential individuals and organisations on the use of 4IR in society:

- **Executive Chairman of the World Economic Forum**: “The fourth industrial revolution is not merely a series of incremental technological advancements, it is an upheaval — a dramatic and wide-ranging shift in the way that value is created, exchanged, and distributed across individuals, organizations, and entire economies” (Schwab, 2019, p. 13).

- **Director-General, UNESCO**: “Promoting open-access AI tools that will encourage local innovation will be one of our priorities. To prepare future generations for the new landscape of work that AI is creating, it will also be necessary to rethink educational programmes, with an emphasis on science, technology, engineering and mathematics — but also giving a prominent place to the humanities and to competencies in philosophy and ethics” (Azoulay, 2018, p. 38).

- **Centre for the Fourth Industrial Revolution: India**: “The Centre for the Fourth Industrial Revolution India has been developed in partnership with the Government of India through the National Institution for Transforming India (NITI) Aayog. Located in Mumbai, the centre serves as a trusted space where local and foreign policy-makers, business executives, technology experts and other key stakeholders exchange insights on the latest technological trends and applications and help shape the future of the Fourth Industrial Revolution” (World Economic Forum, 2020b, p. 8).

- **4IR in Africa**: “The Fourth Industrial Revolution (4IR) — characterized by the fusion of the digital, biological, and physical worlds, as well as the growing utilization of new technologies such as artificial intelligence, cloud computing, robotics, 3D printing, the Internet of Things, and advanced wireless technologies, among others — has ushered in a new era of economic disruption with uncertain socio-economic consequences for Africa” (Ndung’u & Signé, 2020, p. 61).
Recent Conferences

An important 4IR technology for education and for developing systems to achieve sustainable development is artificial intelligence. Symposia and conferences around the world have explored how AI can be used for education and sustainable development. For example, the theme of a recent symposium hosted by UNESCO was “Artificial Intelligence for Sustainable Development” (https://en.unesco.org/mlw/2019). It was attended by more than 1,500 participants from 140 countries (including ministers of education and ICT, other representatives from Commonwealth Member States, and members of the private sector, academia and international organisations). The overall aim of the conference was to explore the opportunities and threats linked to the use of AI in education. Specific topics included: how to ensure inclusive and equitable use of AI in education; how to leverage AI to enhance education and learning; how to promote skills development for jobs and life in the AI era; and how to safeguard transparent and auditable use of education data. A synthesis report on the conference is available at https://unesdoc.unesco.org/ark:/48223/pf0000370308. Over 40 AI projects were presented at the conference, highlighted in a document titled “Artificial Intelligence in Education: Compendium of Promising Initiatives,” which can be accessed at https://unesdoc.unesco.org/ark:/48223/pf0000370307.

At the conference, Professor Mohamed Ally presented a session titled “An AI-Empowered Online One-on-One Tutoring System to Educate Students in Rural Areas.” The full conference programme can be accessed at https://en.unesco.org/sites/default/files/mlw2019-programme.pdf.

A second UNESCO event was themed “International Conference on Artificial Intelligence and Education: Planning Education in the AI Era: Lead the Leap” (https://en.unesco.org/themes/ict-education/ai-education-conference-2019). This conference was attended by around 500 international representatives from more than 100 Member States, United Nations agencies, academic institutions, civil society organisations and the private sector; amongst these were 50 government ministers and deputy ministers. Professor Mohamed Ally attended as an invited guest. The conference provided a platform for Member States, international organisations, civil society groups and the AI industry to:

(1) debate whether skills needed to successfully cope in the AI era can be anticipated, and share experiences on the development of skills that will enable humans to adapt to a society informed by AI;

(2) exchange information on the latest trends in AI and how the trends are shaping education and learning;

(3) assess lessons learned from emerging national policies and strategies for leveraging AI to achieve SDG4; and

(4) strengthen international cooperation and partnerships for promoting the equitable, inclusive and transparent use of AI in education.

A final report on the conference can be accessed at https://unesdoc.unesco.org/ark:/48223/pf0000370967.

At the conclusion of the conference, a report titled “Beijing Consensus on Artificial Intelligence and Education” was published as a call to action for Member States to further the use of AI in education. The Beijing Consensus document can be accessed at https://unesdoc.unesco.org/ark:/48223/pf0000368303.
4IR Technologies to Achieve the SDGs

As the world moves into the Fourth Industrial Revolution, there is a sense of urgency for countries to use 4IR technologies for sustainable development, to provide services to improve all citizens’ quality of life. However, countries must make sure that citizens have the infrastructure to take advantage of 4IR technologies (Pollitzer, 2019). The World Economic Forum (2017) declared that the 4IR is changing the world, because new technologies that combine the physical, digital and biological worlds are impacting all disciplines, economies and industries (Schwab, 2019). The 4IR requires that all sectors focus on the urgent need for collaborative solutions to collective challenges, many of which — such as climate change — are the unfortunate by-product of previous phases of industrialisation and globalisation; however, there is a huge responsibility to ensure that the technologies changing the world do so in ways that reflect common values and deliver broad-based benefits (Schwab, 2019).

A 2019 UNESCO report titled Meeting Commitments: Are Countries on Track to Achieve SDG4? indicates that not only is the world far behind in meeting the 2030 educational sustainability goals, but the ability to accurately address the dilemma is exacerbated by the inability to collect the necessary data (UNESCO, 2019). This is a further reason for countries to use 4IR technologies to educate citizens and develop systems to fast-track the achievement of the SDGs. AI, blockchain and IoT technologies can assist in facilitating this process. The report concludes by “mak[ing] a call for countries and their international development partners to coordinate and finance the collection of data to monitor and deliver on SDG4” (p. 16). Future global projects could make a timely and substantial contribution by responding to the UNESCO call for financing and co-ordinating the collection of data, as well as the monitoring and delivery of educational services to meet SDG4 and other SDGs. Inclusive economies and social development, individual and collective security and peace, and environmental sustainability constitute the foundational aims of the UN 2030 SDGs agenda (Habinak et al., 2019; Rosa, 2017; United Nations, 2015). With conscientious planning and prudent implementation, 4IR technologies can assist humankind in achieving these goals within and between all sectors: culture, society, economy and the environment. As noted by Pollitzer (2019), “the big transformational promise of 4IR is in cyber-physical systems that will merge different digital technologies and integrate them within the physical, digital, and biological spheres. This will produce deep and systemic societal changes at a larger scale and a more rapid rate than previously seen” (p. 76).

Sustainable development is defined in a variety ways; two examples are as follows:

- The United Nations defines sustainability as a movement for ensuring a better and more sustainable well-being for all, including future generations, which aims to address the everlasting global issues of injustice, inequality, peace, climate change, pollution and environmental degradation (Ghobakhloo, 2020).

- “Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs” (Cook, 2019, p. 26).

The authors of this report define sustainable development in the 4IR as “the use of technologies to combine the physical, digital and biological worlds to improve the lives of citizens while existing in harmony with the environment.”
Fourth Industrial Revolution for Sustainable Development in Small States

Small states and developing countries have the opportunity to move directly into the 4IR without going through the previous industrial revolutions. This requires that governments give a sense of urgency and high priority to the transition into the 4IR. This is already happening in some countries that are establishing Centres for the Fourth Industrial Revolution (World Economic Forum, 2020a); however, governments in small states and developing countries need to empower citizens to use emerging technologies for sustainable development in their own contexts (Cissé, 2018).

According to Rudge (2020), “[f]or Small Island Developing States in particular, the Fourth Industrial Revolution could have a truly positive transformative effect — especially if we look at how these economies could join the Creative Industries Revolution. It’s going to take something of a shift in thinking though” (p. 3). The shift in thinking must be done by citizens, all sectors of society, and governments.

Developing countries and small states were limited from fully participating in the previous three industrial revolutions by inadequate infrastructure and expertise, among other factors. Countries are increasingly well positioned to take advantage of digital technologies in the 4IR to advance them for sustainable development so that they can improve the lives of their citizens. Developing countries and small states must make it a priority to adopt 4IR technologies and scale up their implementation (Adhikari, 2020). At the same time, countries should use 4IR technologies to educate citizens in developing the skills required for sustainable development in the 4IR. “Digital technologies such as artificial intelligence (AI), the Internet of Things (IoT) and other advances in information and computer technology (ICT), provide opportunities to improve the education process” (Vincent-Lancrin & van der Vlies, 2020, p. 6) The advent of the 4IR has resulted in a shift from the large computer revolution (Third Industrial Revolution) to the development of smart technologies such as AI, IoT, robotics, and data analytics (Philbeck & Davis, 2019; Qi, 2020). Certain sectors of society, such as finance, e-commerce, business, government, manufacturing and health, are taking advantage of 4IR technologies to grow and to provide quality services to citizens. There is a rising sense of urgency that the education sector must use these technologies to provide flexible education and personalised learning for sustainable development, and to achieve the SDGs (Rizk, 2020; Wozniak, 2020).

Use of Artificial Intelligence for Sustainable Development

The 4IR technology receiving the most attention for education and sustainable development is AI. The following are some common definitions of AI:

- The AI Group of Experts at the OECD define an AI system as “a machine-based system that can, for a given set of human-defined objectives, make predictions, recommendations or decisions influencing real or virtual environments” (Vincent-Lancrin & van der Vlies, 2020, p. 7).
- “Artificial Intelligence (AI) is a scientific discipline aimed at building machines that can perform many tasks that require human intelligence” (Rossi, 2019, p. 127).
- According to Baruffaldi et al. (2020, p. 8), “Artificial Intelligence (AI) is a term commonly used to describe machines performing human-like cognitive functions (e.g., learning, understanding, reasoning and interacting).”

According to Kyllönen (2019):

Digital solutions, the use of new algorithms and artificial intelligence, enables flexible and personalised approaches to learning while the web opens almost unlimited opportunities for learners to
gain new competencies and skills. The role of formal education and especially formal degrees is likely to diminish as the required competencies for working life continuously change, especially since artificial intelligence is already replacing human decision making. (p. 313)

According to Rubin and Brown (2019), artificial intelligence is still young but beginning to be leveraged to learn about students’ interests, habits and patterns in order to promote learning experiences based on unique identified needs.

If this (artificial intelligence) technology is to be accessible to all, it must be taught everywhere. It is through education that it will be placed in the hands of those who need it most. And I guarantee you that if you give them the means, people will find solutions to their own problems. (Cissé, 2018, p. 20)

UNESCO is exploring how AI can help achieve the SDGs, especially SDG4: Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all.

According to Azoulay (2018), as a result of its coordinating role in the SDG-Education 2030 Steering Committee to monitor the achievement of SDG4, UNESCO is in an excellent position to lead this work — by identifying the possible contributions of AI to inclusive education and assessing its potential impact on the future of learning (p. 38).

AI has the potential to: improve the welfare of people; contribute to positive, sustainable global economic activity; increase innovation and productivity; and help with responses to key global challenges, such as climate change, health crises, resource scarcity and discrimination (OECD, 2019b).

Artificial intelligence (AI) is rapidly opening up a new frontier in the fields of business, corporate practices, and governmental policy. The intelligence of machines and robotics with deep learning capabilities have created profound disrupting and enabling impacts on business, governments, and society. They are also influencing the larger trends in global sustainability. (Goralskia & Tan, 2020, p. 1)

The OECD and other organisations also see the potential for AI to contribute to achieving the SDGs.

AI holds significant potential to advance the agenda towards meeting the Sustainable Development Goals. AI can be leveraged for social good and to advance meeting the United Nations Sustainable Development Goals (SDGs) in areas such as education, health, transport, agriculture and sustainable cities, among others. Many public and private organisations, including the World Bank, a number of United Nations agencies and the OECD, are working to leverage AI to help advance the SDGs. (OECD, 2019a, p. 4)

**Education 4.0 for Sustainable Development**

Education has not kept up with advances in the 4IR. Although societies have moved from the First Industrial Revolution (1IR) through to the current 4IR, most education systems are still in the Education 2.0 era rather than Education 4.0 (Figure 1).

Developing countries, because of their location, government structure, and lack of technical expertise and infrastructure, have not been able to take full advantage of the first three industrial revolutions (Adhikari, 2020). As small states and developing countries move into the 4IR, they have the chance to use smart technologies to improve quality and efficiency and thereby reduce the disparity between developed, developing and underdeveloped populations. Countries can use 4IR technologies to deliver education to learners regardless of their status and location, especially in remote locations. For example, a server with a curriculum and learning management system
can be placed on unmanned aerial vehicles (UAVs, or “drones”), which then circle a remote location, allowing learners to access the learning materials using mobile devices with wireless capability. Countries need to use innovative technologies and pedagogies to take education to learners rather than bring learners to education (i.e., physical schools). The next generation of educational systems must prepare learners across the globe for the future by adopting the “good” of 4IR technologies so that the SDGs are met. “AI may particularly help achieve some of the global educational targets identified by the international community in SDG4: Ensure inclusive and equitable quality education and promote life-long learning opportunities for all” (Vincent-Lancrin & van der Vlies, 2020, p. 7).

Education 4.0 is about aligning education systems through the use of 4IR technologies, to personalise learning and provide flexible learning opportunities for all citizens, regardless of location and status (Ally & Wark, 2019a, 2019b; Qi, 2020; Salmon, 2019). The use of online learning and eLearning allows for learner-centred education anywhere and anytime, rather than requiring learners to attend a physical location to learn. The Hole in the Wall Project has demonstrated that learners can be self-directed and can learn on their own (Mitra, 2014). With the Internet and online learning, Mitra (2019) is looking at “hole in the cloud” interventions, whereby learners can use technology to access learning materials in the cloud. This is increasingly possible due to the wide availability of learning materials as open educational resources (OER).

According to Kyllönen (2019), the current education model in the West was designed for the needs of an industrial era, a time of mass production and specific professions. Obedience and basic dexterity alone were a reasonable competence for the time of Spinning Jenny-style technology. This world does not exist anymore. But if we look at the average classroom, the design of the school has remained almost unchanged! The crucial question is, are we truly aware of the demands and expectations this change will force on us? (p. 314)

Dingli and Montalto (2020) concurred, stating that “the methods used have been inspired by the earlier industrial revolutions when an assembly line one-size-fits-all approach was [the] setup in schools” (p. 317).

Certain sectors of society, such as finance, e-commerce, business, government, manufacturing and health, are taking advantage of 4IR technologies to grow and to provide quality services to citizens. There is a sense of urgency for the education sector to use these technologies to provide flexible education and

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<td>• Small classrooms (20–30 students)</td>
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<td>• There is a need to reinvent education in the 4IR.</td>
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**Figure 1.** Industrial revolutions and education revolutions.
personalised learning for sustainable development and to achieve the SDGs.

According to Vincent-Lancrin and van der Vlies (2020), in terms of instruction, AI’s biggest promise lies in the personalisation of learning and learning materials. Personalised learning is an educational approach aimed at customising learning based on students’ individual needs and strengths. AI applications can identify pedagogical materials and approaches adapted to the level of individual students, and make predictions, recommendations and decisions about the next steps in the learning process, based on data from individual students (p. 7).

Developing countries are adopting the old industrial-style school system, which is not suitable in the 21st century, where content exists digitally and new generations of students are comfortable using emerging technologies. Rubin and Brown (2019) argue that today, there is a clear and vocal consensus among all stakeholders that our model of schooling is not effectively preparing students for today, let alone for the challenges and opportunities of tomorrow. They suggest that to close an achievement gap and prepare all students in our evolving societies for success in careers and the future challenges that await them, a radically different approach is needed.

According to Berry (2020), the present learning system is constrained by the structures that emanated from the bureaucratically arranged 20th-century school, which defined teaching and learning as time and place bound. The brick-and-mortar, bureaucratically arranged, factory-inspired school is being displaced across the globe by virtual schools that can be adapted and customised for individualised virtual learning. The technology exists to learn virtually, but educators need training to make the transition to Education 4.0.

What began around the turn of the twenty-first century as electronic learning (e-learning) is evolving rapidly from strictly online learning to artificial intelligence, wearables and an accelerated movement toward technological singularity. On the e-learning end of the spectrum, content is now democratized in ways that we have never witnessed. We are seeing the emergence of a growing amount of free and open learning content (widely called open educational resources or OER), from curriculum to lesson plans to an array of knowledge and skills acquisition opportunities, including Massive Open Online Courses (MOOCS), syllabi, books, etc. (Rubin & Brown, 2019, p. 239)

### Research Questions

This research project was guided by the following questions and sub-questions:

1. What roles can the 4IR and AI play in the implementation of projects?
   - A. What are the emerging 4IR technologies?
   - B. How can these emerging technologies be used to educate Commonwealth and global citizens?

2. What roles can the 4IR and AI play in sustainable development for the Commonwealth and other countries of the world?
   - A. What emerging 4IR and AI technologies can contribute to sustainable development for the Commonwealth and other countries?
   - B. How can these technologies be used to provide services to Commonwealth and global citizens?
LITERATURE REVIEW

4IR Technologies

Some of the most widely used 4IR technologies include AI, robotics, big data, biotechnology, blockchain, cloud computing/technology, extended reality (XR), IoT, and smart sensors. These categories, in turn, contain numerous sub-categories. For instance, AI encompasses single-task bots, digital assistants, machine learning and deep learning. XR includes augmented reality (AR), mixed reality (MR), remote augmented reality (RAR) and virtual reality (VR).

As mentioned, AI, XR and ICT are being applied to holistic, immersive learning environments, as well as in MOOC settings to provide immersive MR learning experiences. Mavrikios et al. (2019) detail how learners in a holistic, immersive learning environment used holograms, mobile technologies and finger-tracking to interact with educational resources and employees. Mavrikios’ team described how holograms could be observed and manipulated simultaneously from any angle by multiple people in a classroom or industrial setting as they discussed tasks. Any component could be “exploded” to enable viewers to see its smaller parts. The users’ mobile devices also displayed annotations, functionalities and content on demand. A second holistic, immersive learning environment example is described by Grodotzki et al. (2018), who observed how students were able to visually explore and test complex engineering procedures through the integrated use of a MOOC, AR, remote and VR labs, and additive manufacturing technologies.

AR, RAR, VR and MR can create what are often intense, highly interactive, immersive real and virtual world experiences, which can stimulate most end users’ sensory perceptions, including learners’. Such technologies are used in education to offer real-life situational experiences, which can enhance student or trainee motivation, engagement and interaction, yielding deep, meaningful learning results. Teaching/learning factories and MOOCs are increasingly merging remote labs, virtual representations of workplace settings and labs, AR/RAR/VR, other mobile devices, and additive manufacturing technologies to produce life-like scenarios and experiences aimed at developing the knowledge, skills and attitudes necessary to live and flourish in the mixed-reality environment of the 4IR era (Ally & Wark, 2019a, 2019b; Block et al., 2018; Grodotzki et al., 2018; Mavrikios et al., 2019; Mourtzis et al., 2018).

Online Learning in Education for Sustainable Development

Catalysed by emerging 4IR technologies, online learning is burgeoning as the desire for interactive, co-created, personalised, on-demand and perpetual learning surges with the transition into the 4IR era (Ally & Wark, 2019b; Buasuwan, 2018; Wan Chik & Arokiasamy, 2019). Traditional formal classroom-based learning is being supplanted by online and MR learning environments that can provide timely, relevant apprenticeships and on-the-job training, such as holistic, immersive learning environments, and MOOCs (Block et al., 2018; Grodotzki et al., 2018; Mavrikios et al., 2019; Mourtzis et al., 2018). Moreover, escalating access to online and mobile learning platforms (Aziz Hussin, 2018; Bhattacharjee et al., 2018; Block et al., 2018; J. Chen et al., 2018; Jia et al., 2019; Lou, 2018; Stock et al., 2018), including a recent initiative to develop a global, AI-enabled, open-source, online learning platform (Duraiappah, 2018), suggests that in the near future, online learning and MR learning will supersede the demand for traditional face-to-face learning (Ally & Wark, 2019b).
In the article “Artificial Intelligence for Education” (Duraiappah, 2018), the Director of the UNESCO Mahatma Gandhi Institute of Education for Peace and Sustainable Development, Anantha Duraiappah, describes an online prototype platform called Collective Human Intelligence (CHI) that allows educators and learners to develop curriculum, lesson plans and assessments in an interactive, immersive and experiential environment, which is supported by AI that is able to provide feedback to students and educators of progress and suggestions to improve learning. (p. 1)

One feature of this online, globally accessible platform is the assignment of a personal bot to each child when the child enters school. This bot draws upon collective knowledge from learners across the globe, while tailoring instructional activities and tasks to meet the unique needs of the learner to whom it is assigned.

**Machine Learning in Education for Sustainable Development**

Machine learning (ML) is a sub-field of AI associated with machines’ ability to learn inductively (Buckreus & Ally, 2020). Unlike rule-based, top-down, purpose-built AI applications, which are programmed to react by following ready-crafted heuristics and rules, ML applications are designed to process sets of historical observations (data records) to infer new patterns or rules arising from the data. Whenever the data are changed, an ML algorithm “learns.” An algorithm learns in the sense that it picks up the modified patterns in a given data set and then is able to present or predict a new result. Machine learning in education can be used to personalise learning for each individual. The system will “learn” about the learner as they progress, then make decisions that will optimise the learning. For example, the system will develop a knowledge graph of the learner to show their progress.

Kučak and colleagues (2018) conducted a systematic review of the literature to determine the value of “machine learning” (or the use of algorithms, drawn from sample data and experiences, to programme software for solving problems) in the field of education. They concluded that ML made a significant contribution in numerous areas of education, such as: (1) prediction of learner performance, (2) fair and equitable assessment of learning, (3) improved learner retention, and (4) provision of administrative duties for educators. Moreover, ML could offer personalised learning, eliminate standardised testing and provide “constant feedback to teachers, students and parents about how the student learns, the support they need and the progress they are making towards their learning goals” (p. 409).

**Blockchain in Sustainable Development**

4IR technologies are emerging at an exponential rate (Brynjolfsson & McAfee, 2014; Wark, 2018) and are rapidly being adopted across cultural, social, economic and environmental sectors around the globe (Ally & Wark, 2019a, 2019b). These technologies can be implemented in various sectors to help achieve the SDGs (United Nations, 2015). For instance, blockchain technologies are being developed to deliver a variety of services, such as the use of smart cards to facilitate migration and fair market farming in India. Such technologies reduce reliance on human resources while increasing reliability, verifiability and transparency, enhancing trust among all parties (Hughes et al., 2019). In education, blockchain can be used to store individuals’ learning and interaction history so that these can be used to prescribe the most appropriate learning materials and identify the help learners need.
Based on an individual’s need and level, the system will match them with the appropriate tutor for help.

Hughes et al. (2019) also offer a number of future scenarios wherein blockchain technology could promote the SDGs. For instance, a blockchain smart food card could be used by migrants in India to simplify logistics, eliminate the need to carry documents, overcome language barriers, and ensure that appropriate state social revenues are billed. The smartcard could also be used to enroll students in new schools and health programmes. This would reduce reliance on human resources, improve efficient and effective delivery of services, provide reliability, verifiability and transparency, and improve trust among all parties. Another blockchain scenario in India could provide increased economic security for farmers, guaranteeing that they are paid state-sanctioned funds for their goods, while encouraging grocers, restaurants and the public to purchase legally obtained, sustainable foods (Hughes et al., 2019).

The application of blockchain technology is beginning in higher education as well, primarily for summative learning outcome evaluation and the management of academic degrees (G. Chen et al., 2018; Sharples & Domingue, 2016; Skiba, 2017). G. Chen and colleagues (2018) envisioned how blockchain could be more fully integrated into the education system by (1) facilitating instructional design, (2) recording and analysing learning behaviours, (3) providing formative and summative assessment, and (4) generating academic degrees in an open, verifiable, reliable, equitable and therefore trustworthy manner. Blockchain could also be used for other administrative management activities, such as the evaluation of teaching performance and professional development.

In addition to teaching skills, organisations need to educate employees on social skills and trustworthiness so that AI can be used for “good” in society (Smolenski, 2016). As individuals complete training using different methods and with different educational institutions, a system using blockchain technology could keep track of the training and award the appropriate credentials to each individual.

**Education 4.0 in Sustainable Development**

The United Nations Sustainable Development 2030 Agenda contains 17 SDGs and 169 targets intended to help guide all sectors of society to improve the livelihoods of the world’s residents (Pollitzer, 2019; Rosa, 2017; United Nations, 2015). One important SDG for education is Goal 4: “to ensure inclusive and equitable quality education and promote lifelong learning opportunities for all” (Rosa, 2017, p. 14). Some countries have started to implement 4IR technologies for sustainable development. For education, there are predictions that 4IR technologies will become self-organising and will play a major role in instructional delivery and in providing support to learners (Mitra, 2014, 2019). Learning will move toward individualisation and learner centredness, due to 4IR technologies such as AI, learning analytics, and the IoT (Aker, 2020; Chai & Kong, 2017; Mitra, 2014; Popenici & Kerr, 2017). A study conducted in a developing Commonwealth country examined the use of VR and a mobile learning platform to provide a personalised learning simulation based upon learners’ reactions to stimuli (Bhattacharjee et al., 2017). The researchers designed an immersive model using the “innate natural learning process in humans” (p. 236) to personalise the virtual lesson simulations. They concluded that their “learning model [was] immersive and [gave] long term retention while enhancing creativity through reinforced customization of the simulations” (p. 236). The 4IR era will dramatically change the role of teachers, with many becoming “4IR” or “digital” teachers, using deep-learning technologies such as AI, robotics, big data, the IoT, etc. (Ally, 2019). The World Economic Forum (2017) foresees teachers having to adopt AI and robotics to teach in the 4IR.
There is a need to bridge the “AI divide,” “robotic divide” and “4IR divide” so that teachers and learners can be ready for the 4IR.

Organisations such as COL are helping countries toward sustainable development by providing learning opportunities to citizens. COL emphasises “learning for sustainable development” using online and distance education for lifelong learning that leads to sustainable development (Aoki, 2020; COL, 2015; Grimus, 2020). To fast-track learning for sustainable development and deliver education in emergency situations, 4IR technologies will be vital.
This report is generated from a research project integrating primarily qualitative data from a review of relevant literature, and from interviews with international experts in 4IR, AI and other emerging technologies. The aim was to answer the following research questions, first identified in the Introduction (see Appendix A for the interview questions).

**Research Questions**

1. **What roles can the 4IR and AI play in the implementation of projects?**  
   A. What are the emerging 4IR technologies?  
   B. How can these emerging technologies be used to educate Commonwealth and global citizens?

2. **What roles can the 4IR and AI play in sustainable development for the Commonwealth and other countries of the world?**  
   A. What emerging 4IR and AI technologies can contribute to sustainable development for the Commonwealth and other countries?  
   B. How can these technologies be used to provide services to Commonwealth and global citizens?

The literature included in this study came from four sources: (1) the researchers’ personal libraries, (2) a systematic review (Gough et al., 2012; Hemingway & Brereton, 2009; Oakley, 2012) of pertinent peer-reviewed journal articles from 1 January 2017 to 31 December 2019, (3) final reports from world organisations such as the World Economic Forum and UNESCO, and (4) interviewee publications, reports, links to web resources, and other recommended resources. Ethics approval for the study was granted by Athabasca University.

**Systematic Literature Review**

A university meta-database search engine was used to conduct a comprehensive search of relevant academic peer-reviewed journal articles. Full-text searches were conducted using the following keyword combinations: (1) “fourth industrial revolution” AND “technology for sustainable development,” (2) “fourth industrial revolution technology” AND “sustainable development goals,” (3) “fourth industrial revolution” AND “sustainable development goals” AND *education* AND *technology*. (Quotation marks ensured that entire phrases were found in a document, “AND” identified groups of keyword phrases in a document, and “*” ensured that all possible suffixes for a word were searched for in a document.) In addition to including the aforementioned keywords, the article had to be in an English-language, peer-reviewed journal located in a university-subscribed or open-access journal database, and published between 1 January 2017 and 31 December 2019 (Table 1). The article content also had to answer at least one of the research questions posed above. Any article that did not fit these criteria was excluded from the study. This excluded articles in other languages, which is a limitation of this study.

Both researchers conducted the initial search together to establish searching procedures and inclusion/exclusion criteria. One researcher then completed the remaining keyword searches, compiling a list of promising titles. The university meta-database keyword searches produced 266 potential articles with 47 duplicates, yielding a total of 219 unique titles (Table 2).
The second researcher then analysed the abstracts from the 219 unique articles for their ability to fit the first three established inclusion criteria while not matching any of the exclusion criteria (Figure 2). This led to the rejection of a further 151 articles, leaving 68 articles for full-text review. The second researcher conducted the initial full-text review of these remaining articles based upon the final inclusion criterion, which was their ability to answer one or more of the research questions. The results of this full-text review were then

**Table 1. Inclusion/exclusion criteria.**

<table>
<thead>
<tr>
<th>Inclusion Criteria</th>
<th>Exclusion Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Article contained keyword search combination(s)</td>
<td>Article did not include at least one keyword search combination</td>
</tr>
<tr>
<td>Article came from peer-reviewed English language journal</td>
<td>Article was not a journal article</td>
</tr>
<tr>
<td>Article was published between 1 January 2017 and 31 December 2019</td>
<td>Article was published before 1 January 2017 or after 31 December 2019</td>
</tr>
<tr>
<td>*Article answered at least one research question</td>
<td>Article was not included in university-subscribed or open-access journal database</td>
</tr>
</tbody>
</table>

*Note: Inclusion criterion used for final full-text article review.

**Table 2. Number of journal articles identified by keywords, by journal database.**

<table>
<thead>
<tr>
<th>Journal Database *</th>
<th>Number of Journal Titles</th>
</tr>
</thead>
<tbody>
<tr>
<td>ScienceDirect</td>
<td>125</td>
</tr>
<tr>
<td>Academic Search Complete</td>
<td>56</td>
</tr>
<tr>
<td>Business Source Complete</td>
<td>32</td>
</tr>
<tr>
<td>SociINDEX with Full Text</td>
<td>13</td>
</tr>
<tr>
<td>Academic OneFile</td>
<td>12</td>
</tr>
<tr>
<td>Expanded Academic ASAP</td>
<td>5</td>
</tr>
<tr>
<td>General OneFile</td>
<td>4</td>
</tr>
<tr>
<td>Canada In Context</td>
<td>3</td>
</tr>
<tr>
<td>Emerald Insight</td>
<td>3</td>
</tr>
<tr>
<td>General Reference Center Gold</td>
<td>3</td>
</tr>
<tr>
<td>Literature Resource Center</td>
<td>3</td>
</tr>
<tr>
<td>Student Resources in Context</td>
<td>3</td>
</tr>
<tr>
<td>Communication &amp; Mass Media Complete</td>
<td>2</td>
</tr>
<tr>
<td>CINAHL Plus with Full Text</td>
<td>1</td>
</tr>
<tr>
<td>InfoTrac Computer Database</td>
<td>1</td>
</tr>
<tr>
<td><strong>Total number of titles</strong></td>
<td><strong>266</strong></td>
</tr>
<tr>
<td><strong>Less: Duplicates</strong></td>
<td><strong>– 47</strong></td>
</tr>
<tr>
<td><strong>Total number of unique titles</strong></td>
<td><strong>219</strong></td>
</tr>
</tbody>
</table>

*Note: Arranged in order from most to least number of journal article titles.*
re-examined by both researchers, confirming 100 per cent agreement with the initial full-text analysis results. It was concluded that 36 articles did not answer at least one research question, therefore yielding a final total of 32 articles that matched all inclusion criteria. (These 32 articles are listed with an asterisk in the reference section.)

**Interviews with 4IR Experts**

Based upon their knowledge and expertise in the identified topic areas, 48 4IR international experts from academic, government, private enterprise and civil service sectors across the globe were invited to join the study. Of these, 12 experts (or 25 per cent of those invited) completed interviews. Approximately two weeks before the planned interview date, respondents received a copy of the interview script (Appendix A). Recorded interviews were conducted by telephone or online in virtual rooms. Respondents were asked to edit and verify the transcription of their interview before their interview was processed for analysis purposes.

The results reported herein include data from six of the interviews. Three of these interviewees were from developing Commonwealth countries, and the other three were from developed Commonwealth countries. Developed nations are considered to be more industrialised and to have higher per capita income levels than developing countries. These six interviews were purposely selected for their ability to provide a rich picture of the phenomena under study, in a manner that added greatest value in terms of this project’s aims.

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**Figure 2. Selection of relevant academic peer-reviewed journal articles.**
Adapted from Moher et al. (2009). CC BY.
INTERVIEW DATA ANALYSIS PROCESS

The highest level of coding labels (or “parent codes”) in the qualitative coding framework were drawn from the main sections of the interview script. Sub-code labels (or “child codes”) and sub-sub-code labels (or “grandchild codes”) were established under the parent codes as the two researchers coded the first two interviews together. The first researcher then coded a third interview and the second researcher reviewed the coding results, ascertaining 100 per cent agreement with the first researcher. This pattern of the first researcher doing the initial coding and the second coder verifying the results was maintained for the three remaining interviews. One hundred per cent agreement between coders was established throughout this process.

Twelve parent codes were identified. Four parent codes related to demographics; these included the respondents’ geographic location, educational and experiential background, and employment sector(s). Seven parent codes related to the topic of SDGs and education: level of country development, 4IR technology list, educating citizens, healthcare, other services, and 4IR technology contributions to sustainable development (including benefits, challenges and opportunities). A final parent code entitled “uncoded” contained units of data that did not fit anywhere else in the coding framework (e.g., one respondent said, “Okay,” another said, “So I have listed three.”). The unit of analysis was the sentence. There were 775 coded units in all. Of these, 238 units (or 30.7 per cent of all units) were coded to demographics, 534 (68.9 per cent) to SDGs and education, and three (0.4 per cent) to uncoded.
RESULTS AND DISCUSSION

This report is based upon cumulative data results from the six 4IR expert interviews described above, along with four literature sources: (1) the researchers’ personal libraries, (2) 32 peer-reviewed journal articles generated from a systematic review of the literature, (3) final reports from world organisations such as the World Economic Forum and UNESCO, and (4) publications, reports, links to web resources, and other resources recommended for review by the interviewees.

Interviewee Demographics

GEOGRAPHIC LOCATION

Of the six 4IR expert interview respondents included in this report, three came from developed Commonwealth countries: one was from Canada and the other two were from the United Kingdom. The remaining three 4IR expert respondents each lived in a developing Commonwealth country: India, Malaysia and South Africa.

EDUCATION

Four respondents had PhDs related to 4IR technologies. Two of these came from developed countries, and the other two came from developing countries. Three of these four had computer science degrees related to AI or information technologies; the remaining one had a degree in learning technologies. One respondent from a developing country had a master’s degree related to the 4IR in general. The final respondent, who lived in a developed country, had non-formal education on the 4IR and 4IR technologies.

EMPLOYMENT SECTOR

At the time of the study, five respondents were employed in the field of academia. One respondent was employed as a Professor of Computer Science at a Canadian university. This professor was also the co-founder of the first massive open online course (MOOC) production company. A second respondent was a lecturer in the Institute of Educational Technology at the British Open University. A third respondent was the Deputy Director of Learning Technologies and a Distinguished Educator at a university in Malaysia. This respondent was also a Certified Professional Technologist on the Malaysian Board of Technologists. The fourth respondent worked for a non-profit educational institution in South Africa. This respondent worked in project management, monitoring, evaluation, and research in educational areas related to AI, ICT, applied linguistics, language learning, literacy, teacher development, institutional leadership, and refugee education. A fifth respondent was the head of a data analytics cell, an officer of special duty in a premier think-tank for the government of India, and a lecturer at various universities. The final respondent worked for an international non-profit organisation. This respondent’s current role was to focus upon AI and gender implications, although this respondent also worked on other projects, including ones that assisted with government procurement of digital services.

One of these respondents had between zero and four years of experience in this sector, two had between five and nine years of experience, one had between ten and 14 years of experience, and the final respondent had more than 30 years of experience. Two respondents worked with governments in developing countries. One had been employed in his sector for less than four years; the other had been working on specific projects with the government for five to nine years. Four respondents were engaged in the private sector. Three had worked in this sector for five to nine years, while one had been employed for between 15 and 19 years. Finally,
two respondents had worked in the public sector; one had worked for a non-governmental organisation for between five and nine years, while the other had worked generally in the public sector for the same period of time.

EXPERIENCE

One respondent from a developed country had substantial research experience as well as some teaching experience on the general topic of 4IR. A second respondent also had teaching experience in relation to the general topic of the 4IR, while a third respondent, from a developing country, had significant experience in this area. This third respondent was highly engaged in the development of international initiatives, designing, implementing, monitoring, evaluating and conducting research on various programmes, especially in developing Commonwealth countries. This respondent also taught essential skills and 4IR skill development as part of these international initiatives. In describing one project, this respondent said, “So, we rolled out in 50 schools in Limpopo [northern South Africa] over two and a half years with a tablet programme and the PC-based programme, and measured the effects, and so on and so forth.”

All respondents had experience in teaching about 4IR technologies and how to use these technologies. Four reported having experience in designing and developing specific 4IR technologies: AI, big data, cloud computing, IoT, learning management systems, network and ICT systems, robotics, and mobile technologies. Two respondents had experience in the social and ethical implications of 4IR technology integration. Finally, three reported extensive research experience with these technologies.

Findings for the four research sub-questions are presented before the two overarching questions are addressed in the remainder of this Results section.

What Are the Emerging 4IR Technologies?

Arranged in alphabetical order, the synthesised list of emerging 4IR technology areas mentioned in the reviewed literature and interviews included:

- additive layer manufacturing (including rapid prototyping and 3D printing)
- AI
- big data
- biotechnology
- blockchain
- cloud computing/technology
- cyber-physical systems
- extended reality
- gamification
- immersive worlds
- information and communication technologies
- Internet of Services
- Internet of Things
- interoperability
- learning factories
- mobile devices/learning
- nanotechnology
- networking
- quantum computing
- smart cities/buildings/infrastructures
- smart factories
- smart sensors
- teaching factories
Numerous underlying technologies were listed within these broad 4IR technology areas. For instance, one respondent identified two AI sub-sets, “smart” and “idiot savants.” Smart AI consists of two categories: artificial general intelligence (AGI), which can perform a variety of tasks, learn, and improve itself, and artificial super intelligence (ASI), which includes AI that is able to surpass human thought capabilities. The “idiot savant” sub-set is also known as “artificial narrow intelligence” (ANI) and encompasses single-task AI technologies, such as speech recognition or voice assistants. Similarly, the XR list encompassed augmented reality, cinematic reality, mixed reality and virtual reality technologies. Nested within these underlying technologies were other technological layers as well. To illustrate, discussions on AR included the incorporation of holograms, mobile/wearable devices, and ICT, among other technologies.

The reviewed literature and interview data also indicated a rising trend towards the seamless integration of technologies. Mobile and wearable technologies, for example, offer increasingly seamless and invisible yet complex arrays of plug-and-play hardware technologies and cross-platform software applications that are accessible through a growing myriad of wireless ICT. Smart buildings, cities and other infrastructures typically rely upon an operational network of devices/sensors, communication networks, cloud repositories/data processing, analytics, and actuators or user interfaces/services (Jia et al., 2019). Microsoft (2019) recently unveiled a new HoloLens keynote presentation package. In the second phase of development, Azure speech-to-text (STT) technology, English transcription software, and Azure language translation technology were used to translate the speech into Japanese, a language in which the test subject could not communicate. Finally, AI neural text-to-speech (TTS) technology was applied to render a life-size hologram that used the subject’s natural voice tones and inflections to deliver linguistically accurate speech in Japanese. The prevalent integrating component within and between these merged technologies was AI.

A total of 63 units were coded in response to the request for interviewees to list the emerging 4IR technologies that they were aware of. The 4IR technology most discussed by respondents was AI (n = 37 units, or 59 per cent of all units coded to this category; see Figure 3). In the AI sub-category of robotics, interviewees mentioned stationary, ambulatory, remote-controlled and humanoid robots, as well as UAVs and autonomous vehicles. Deep learning, reinforcement learning, artificial neural networks, and natural language processing were identified as sub-categories of machine learning. Digital and virtual assistants were also mentioned. One respondent-recommended resource was the book Artificial Intelligence in Education: Promises and Implications for Teaching and Learning (Holmes et al., 2019), wherein a taxonomy of AI technologies for learning was presented. This taxonomy included: intelligent tutoring systems, dialogue-based tutoring systems, exploratory learning environments, automatic writing evaluation, learning network orchestrators, and AI-driven language learning.

The 4IR technology sub-category that generated the second-most units from interview data was “general comments” (n = 6 units, or 9 per cent of all units coded to this sub-category). This sub-category included such comments as, “There is a lot out there. So much that it is even difficult to start,” and, “That list is very, very long.” The sub-code “unsure” held the third most units (n = 5, 8 per cent of units). Comments in this subsection indicated hesitancy to agree with other people on whether some technologies should be included in the 4IR list. For instance, one respondent said, “There are a lot of technologies that people would consider as being 4IR. For many of these technologies, maybe it’s too early to say that they are 4IR.” Blockchain and nanotechnology sub-categories were the fourth most frequently mentioned (n = 4 units, 6 per cent of units). All remaining 4IR technologies in the list were referred to only once or twice.
Some respondents pointed out that AI has been around since at least the 1950s; one respondent had begun working in the field of AI in 1970. Yet recent advances in some areas of AI suggest that it remains an emerging 4IR technology. To illustrate this point, one respondent said:

Applications in AI have been deployed for 20-plus years and used successfully, but it is invisible or, until recently, was invisible. . . . Ten years ago they found some advances in the older technology that turned it into a very powerful tool. [One advance] is called “deep learning.” It’s really just an extension of something called a “neural network”; add the deep learning enhancements and all of a sudden it has powerful capabilities. . . . The second area, which is more general, but doesn’t have the same résumé of exciting applications attached to it, is called “reinforcement learning.”

The pervasiveness of AI technologies was evident not only in the interview discussions but also in the literature. Twenty-five (or 86 per cent) of the 32 articles included in the literature review either mentioned AI in general or discussed specific AI technologies in relation to the SDGs. This leads to the conclusion that AI may indeed be the “general purpose technology” (Brynjolfsson & McAfee, 2014) that is precipitating the paradigm shift from the Third Industrial Revolution to the 4IR — a notion that has profound implications for the adoption of 4IR technologies to attain the SDGs for individuals, nations and the global community. (This comment is elaborated upon in the section below titled “What Can Emerging 4IR and AI Technologies Contribute to Sustainable Development?”)
How Can These Emerging Technologies Be Used to Educate Commonwealth and Global Citizens?

Data collected from the reviewed literature and interview respondents focused upon six key themes in addressing how emerging 4IR technologies could be used to educate Commonwealth and global citizens. These themes were: (1) transitioning from the Education 3.0 era to the Education 4.0 era, (2) access to learning, (3) multidisciplinary learning, (4) employing AI learning technologies, (5) personalised learning, and (6) the benefits, challenges and opportunities related to using these technologies for education.

TRANSITIONING FROM THE EDUCATION 3.0 ERA TO THE EDUCATION 4.0 ERA

The overarching theme emerging from the data was the recognition that as the global society transitions from the 3IR to the 4IR, the existing Education 3.0 era is being supplanted by Education 4.0. Moreover, this shift in educational paradigms is being triggered by the emergence of 4IR technologies, especially AI.

Education 3.0 is designed to replicate the 3IR factory model. It is based upon the behaviourist paradigm and pedagogical approach to learning (Wark, 2018). A government-approved curriculum is delivered en masse in formal learning contexts, such as K-12 classrooms. The aim is to transmit knowledge and to develop instrumental reasoning among learners so they may become functional members of society. The following comments reflect characteristics of Education 3.0 learning environments:

[Respondent 1]: The idea starts with the recognition that in most schools, children sit in their class and are all taught at the same pace.

[Respondent 2]: In a class environment in that particular option or portion, there might be a fear or issue that if the student fails, then the teacher might think good or bad about them, and friends might think something about them.

The emerging Education 4.0 era appears to foster a more learner-centred or learner-determined approach to education. Learning in the Education 4.0 era prepares learners for a mixed-reality world, encompassing their personal learning environments (PLEs) — consisting of the private, social, work and school contexts, tools and resources that the self-determined learner employs in order to learn — while merging their authentic real and virtual worlds to generate an immersive, meaningful, lifelong, holistic learning experience (Ally & Wark, 2019a, 2019b; Grodotzki et al., 2018; Wark, 2018). To illustrate, one interview respondent said:

Previously, I was talking about the holograms, drones and AR. We could combine those technologies for global education. Combining holograms, drones and AR would really help people who live in tropical weathers, such as Malaysia, in experiencing snowstorms.

At this point, the authors would like to clarify the use of a few terms found in this report. Although some reviewed articles use the terms “learning factories” or “teaching factories,” the authors reject the use of the word “factories,” as it may connote references to 2IR and 3IR manufacturing schemas and related educational paradigms. The descriptions of 4IR teaching and learning factories provided in the reviewed literature do not conform to notions of these formal manufacturing or factory production models. Instead, the teaching and learning factories of the 4IR emulate the Education 4.0 paradigm, and they employ emerging pedagogies and learning environments that are learner determined, holistic and immersive in nature. The term “teaching factories” may also invoke associations with the behavioural educational paradigm of the previous educational eras. Thus, to intentionally reflect notions and practices of the new 4IR and Education 4.0 eras,
the remainder of this report uses the term “holistic, immersive learning environments” instead of “teaching factories” or “learning factories,” unless providing direct quotes from original sources.

Research, education and innovation are hallmarks of holistic, immersive Education 4.0 learning environments (Ally & Wark, 2019a). Such environments enable learners to use ICT and XR technologies to experiment with applying theoretical knowledge to innovative ideas and products. Holistic, immersive learning environments, as well as remote environment-enabled MOOCs, for example, enable learners to safely engage by virtual means with workers in the field while gaining practical real-world knowledge and experience. These interactions are beneficial to both parties. Learners can provide business and industry managers and workers with the latest theory, research and technological advances, while discovering practical implementation benefits and challenges in real business and industry settings without disrupting workflows (Block et al., 2018; Grodotzki et al., 2018; Mavrikios et al., 2019; Mourtzis et al., 2018).

ACCESS TO LEARNING

A prevalent theme emerging from the data was access to learning. When talking about current access to education, one expert respondent relayed the following personal observation:

At these [international] conferences I met people from the developing world and it was clear, time and time again, that they were saying, “Why are we talking about AI in education when we don’t even have the infrastructure? We don’t have electricity. We don’t have Internet access. We don’t have the hardware that is necessary. So why are we talking about this?” These are very important questions.

Two other respondents envisioned how 4IR technologies might improve access to education for learners in remote locations and developing countries:

[Respondent 1]: At the intersection of technology and open resources we now have a new pool of co-created knowledge we can meaningfully curate and draw from. . . . In my opinion, the global learning environment becomes a very connected landscape with these technologies.

[Respondent 2]: Maybe giving a student in a developing world access to a digital AI-based tutor is far better than them having no access to teaching at all.

The sentiments expressed by these expert respondents is echoed in much of the reviewed literature. The potential role of AI in Education 4.0 is notably highlighted in the collective synthesis of these data. AI is expected to significantly transform the way that educators work by offering teaching aids and relieving them of mundane tasks, such as keeping records and sending out notifications or reminders. Furthermore, it is anticipated that AI will revolutionise personalised learning, improve access to knowledge, and potentially foster greater inclusivity (Azoulay, 2018; Duraiappah, 2018; Hodson, n.d.; UNESCO, 2019a).

Interviewees concurred with the data drawn from the reviewed literature, pointing out how the advent of emerging technologies and online learning will generate more meaningful interactions and authentic experiences, the globalisation of learning, knowledge co-creation, and the expansion of learning communities and learner choice, among other benefits. A sampling of such comments included:

[Respondent 1]: Having these holograms as an expert, for instance let’s say that you could have Tim Cook from Apple in your classroom — how cool would that be? And learning with the experts both in synchronous and asynchronous landscapes I think would be very interesting. We could use these learning scenarios and have the authentic experience from experts.
[Respondent 2]: I do think that the technologies that we have at our fingertips now are enabling more meaningful types of distance education, for starters. And they’re creating a new world environment where it’s almost the globalisation of education, if you want to think about of it that way. . . . At the intersection of technology and open resources we now have a new pool of co-created knowledge we can meaningfully curate and draw from. There is great potential for technology to aid in both creating and expanding new types of communities and exchanges.

[Respondent 3]: In education, a lot of the technologies that we are developing today are around self-learning or self-paced learning, when you have things like MOOCs or things of this nature where people can go and try on their own.

LIFELONG LEARNING

Another access-to-learning sub-topic that often intersected with online learning discussions in the literature and interviews was lifelong learning. In discussing how various employment and social enterprise sectors will have to introduce ongoing training to employees and volunteers to remain abreast of developments in the 4IR, much of the literature and many interviewees noted the element of lifelong learning in the new era. As one respondent commented, “We can no longer, and this is my personal experience as well, you can no longer get a degree and decide, ‘Well, that’s done.’ So, development, personal development, and national development plans have to adjust to that.”

One interview respondent noted that learning was not only lifelong, but life wide as well. In talking about the lifelong skills needed “to think critically about the world, to interpret the world dynamically,” this respondent concluded, “I think they’re important whether you’re in conventional work, or you’re just trying to live your life, you know, whether you’re trying to improve the companies you work for, or you’re trying to craft your family, these skills are equally important.”

While most of the literature and interview data surrounded the recognition of lifelong learning in the 4IR era, some of the data discussed how emerging technologies, especially AI, might support lifelong learning goals. To illustrate, one respondent concluded her discussion on lifelong learning by saying, “And then digital assistants could be used in ways to help with setting lifelong learning goals.”

In a recent UNESCO Blue DOT publication, Kemato (2018) also detailed how AI could be used to create parallel micro-level skill development models for a learner, which could not only track skill acquisition but also present job opportunity choices and career path scenarios. When prerequisite skills are absent, AI that is cognisant of existing curricular options could then recommend learning resources and track the learner’s progress towards the attainment of these skills. “In other words, AI can produce online courses from identified skills and so bring vocational training and lifelong learning for billions of learners” (p. 25).

INTERDISCIPLINARY AND MULTIDISCIPLINARY LEARNING

The Education 4.0 holistic, immersive curriculum will be interdisciplinary and multi-disciplinary in nature (Ally & Wark, 2019a). In other words, the new curriculum will integrate and synthesise knowledge and skills from numerous disciplines, as well as draw people together from various disciplines to work on projects or achieve certain goals. One need only reflect on the complex, integrated nature of emerging technologies, or the adoption of authentic problem-based and discovery-based learning approaches to appreciate the need to develop interdisciplinary and multidisciplinary knowledge and skills among learners. Data results suggest that AI, XR, the IoT and ICT, for example, can facilitate interdisciplinary and multidisciplinary learning experiences in holistic, immersive learning.
environments, or MR MOOC environments (Aziz Hussin, 2018; Morgan, 2017; Mourtzis et al., 2018).

EMPLYING AI LEARNING TECHNOLOGIES

A myriad of examples of AI learning technologies and how they can be used in the Education 4.0 era emerged from the reviewed literature and interview data. The most common AI topics associated with this theme focused upon immersive learning, “machine learning” (defined as using algorithms to programme software using sample data and experiences to solve problems) and learning platforms. AI-driven game-based learning was mentioned in some articles and one interview.

PERSONALISED LEARNING

According to much of the reviewed literature and interview data, technology-facilitated personalised learning appears to be a cornerstone of Education 4.0. Most of these data provided general statements or examples of how emerging technologies can be used to facilitate personalised learning, as the following interview comment illustrates:

So, this is a broad concept, and there are a lot of technologies that are developed around this concept, like how you personalise the learning to a particular individual speed, or liking, or all other things. So, if they are doing things at their own pace, they can always try the same thing even if they are doing it wrong, they can try it for 10–15 times to develop themselves.

Benefits, Opportunities and Challenges

BENEFITS AND OPPORTUNITIES

An exhaustive list of the benefits of, and opportunities for, using 4IR technologies could be drawn from the reviewed literature and interview data. Many of these benefits and opportunities are detailed throughout this report, so only a few are highlighted here. For instance, customised learning was frequently cited as a benefit that 4IR technologies offer. As one respondent surmised, “AI can be used to help educate people by creating custom learning environments that allow learning to occur on an individualised basis instead of [using] a mass market approach.”

Related to the concept of customised learning was the idea of learner empowerment. One respondent quipped, “The kinds of technologies that I think are most interesting are those kinds of technologies that empower people; as I was saying earlier, like the technologies that empower teachers to be better teachers.”

Greater access to human and non-human resources was also noted in the literature and interview data. For instance, one respondent observed: “At the intersection of technology and open resources, we now have a new pool of co-created knowledge we can meaningfully curate and draw from.”

CHALLENGES

Beyond the issue of learner access to technologies and educational opportunities, discussed in the “Access to Learning” sub-section above, perhaps one of the greatest challenges in using emerging technologies to educate Commonwealth and global citizens is to support all educational stakeholders during the paradigm shift that is occurring as the world moves into the Education 4.0 era. For instance, some interview respondents pointed out the need for local, national and international institutions, as well as individual learners, to adopt a new mindset:

Instead of talking about things like work-integrated learning, we need to talk about learning-integrated work, where everything that we do needs to be cognizant of the new technologies that are emerging on a constant basis. And then decisions need to be taken about which of those are relevant and how
they can be best used. Then that also creates effects, especially in environments where the education sector may be quite a large part of the economy.

The second challenge noted in the literature and interviews was ensuring that the educational sector could keep pace with industry. As one respondent noted:

One of the presentations I saw recently pointed out very clearly that the word “industrial” in the fourth industrial revolution is the key in the sense that a lot of industry is really moving forward very, very rapidly, and that, in many senses, education has been left behind. Education is just way behind that. And I’m just talking in the developed world. In the developing world, it’s even harder in many, many ways. And so I think many of the AI technologies that we’ve discussed may have a role to play in education.

The third challenge is to ensure prudent implementation of appropriate technologies. One respondent provided these words of caution:

We have to be careful that we are not going down the imperialist “we know best; we have the technology” route. . . . Instead of closing the gap between people in the developed and developing world, if we are not careful, the use of AI technologies is just going to make the gap bigger.

Another challenge in the adoption of the new educational paradigm is teacher education, as this respondent explained:

The other side, of course, is that there’s reluctance on the part of teachers to embrace technology. And part of that is linked to the type of pedagogy that teachers prefer. So teachers who are more collaborative by nature or lean towards constructivist views of education tend to embrace technology more, I think. But those who are more didactic have a real challenge in understanding how technology can be used in their classroom — coupled with a real fear of technology itself. They might have a mobile phone, but they don’t really use it; they’ve got a son who will help them set it up, so they’ve got one or two functions that they will maybe not understand but will be able to use. There’s a big push in South Africa right now towards literacy, early literacy, because international testing results are so bad; early literacy isn’t really working or happening. . . . So, it’s a big challenge, I think, getting teachers to understand technology.

One respondent illustrated why teacher training is imperative:

If a robot or bot was in your class, how do you respond to this scenario? How do you treat that robot? Would you treat the robot as a teacher or would you treat that robot as a teaching assistant, or as a student? It really changes the landscape of education. In relation, we’ve seen Sophia the robot. She or it has been given citizenship by Saudi Arabia. So, if robots were to become like humans, how would that change the landscape of education? Would we treat them as learners? Would we treat them as teachers or teaching tools? So that really changes the dynamics of learning; to a certain extent, crossing to the biological world, if those bots or robots could have physiological sensors in them and the AI could predict our emotions during learning. These 4IR technologies are, I would say very smart, yet very challenging, because are the teachers today really equipped for that? AI is changing very quickly, so how do we respond to that change with not only the technological competencies and skills, but the pedagogies? How do we integrate that well to make students ready for the 4IR?

A third respondent mulled over how emerging technologies might be used in education:

So, it is a question of whether these technologies are being used to replace teachers or to support and augment teachers. Although the developers robustly deny it, the existing AI tools that I listed
are mostly, in effect, designed to replace teachers. If we could have technologies that are designed instead to help teachers, then that would be a much more effective use of these technologies. . . . Maybe giving a student in a developing world access to a digital AI-based tutor is far better than them having no access to teaching at all. However, I still think that is a short-term approach and I still think that we would be far better off developing technologies, which hasn’t yet happened, to support teachers in doing what teachers do and could, for example in a developing country, support unqualified teachers to develop their skills and become better teachers. So, in that way, the technologies could be very helpful.

Fear, mythology, fake news, and ethical concerns are also notable challenges to 4IR technology integration during the shift to the Education 4.0 era. For instance, one interview respondent stated, “I think at this moment in time, there are so many concerns that I would have around the use of a lot of these technologies, because of the data gap and ingrained biases, etc.,” concluding: “I would be very cautious about the way that we use these technologies to educate people.”

Another respondent said:

I think the notion of robot teachers, if that’s not fearful, I don’t know what is. So, I think it’s very important that we address those myths and make sure that we talk about what really is possible, what really might happen; try and get away from the nonsense that you see in the newspapers.

A second respondent offered the following comment:

There are a lot of myths both within the world of computer scientists and the technologists, and entrepreneurs, and a lot of that is taken on board by the policy makers. Whenever I give a talk somewhere, and these conferences I’ve been to, the big picture is always a robot, as if to say we’re going to replace teachers with robots.

The UNESCO report *I’d Blush If I Could* (West et al., 2019) details the gender divide that is growing in most parts of the world: “Today, women and girls are 25 per cent less likely than men to know how to leverage digital technology for basic purposes, four times less likely to know how to programme computers and 13 times less likely to file for a technology patent” (p. 4). The report goes on to point out that AI technologies often reinforce, if not further promote, gender bias. This phenomenon is likely due to the dominant number of AI designers who are male, some of whom reflect the view that women are “not fully human beings” — for instance, by designing AI technologies such as digital assistants that have female voices, like Siri and Alexa (Richardson, 2015; West et al., 2019). The most effective way to reduce gender bias in AI is for countries, international organisations such as UNESCO and COL, and educational institutions to continue to promote gender equality policies, and to financially support the inclusion of girls and women in digital education programmes, as well as to provide incentives that encourage industries to hire women in the field of AI.

One respondent summed up some of the ethical issues that must be addressed:

[T]here’s a real challenge facing us in terms of ethics that I don’t think has been adequately addressed on an international scale. There’s a whole range of ethical and related issues that come up. Bias in AI is a major component, as I mentioned. I have already said that half the world is offline, and AI programmes are created from the data of the half that is online. So that means we’ve created yet another system which is in many ways favourable to people who have, rather than people who have not. . . . Issues of privacy and security are also very real.

Another concern we need to acknowledge and face is that the people who are in “the room where it happens,” to quote Lin-Manuel Miranda, are not AI practitioners or trained in AI. And those are people who actually need a depth of knowledge, because they are the ones that we’re relying on to
keep us safe. They’re the ones that we’re relying on to create policies that allow companies to grow, yes, but also to keep our data and institutions secure, and keep our personal data and information in our hands. They are supposed to create the policies, the curricula, and the plans for education going forward. They are supposed to really connect the world using these new technologies. And yet very few have a deep understanding of what AI can do or how it works. This is partially evidenced by what I would call an incredibly low political and financial investment in AI for governance itself, despite incredible efficiencies in other spheres.

A salient solution to address these challenges is to educate governing bodies, policy makers, teachers, learners and other global citizens on what 4IR technologies are and how these technologies can be used to attain the SDGs.

What Can Emerging 4IR and AI Technologies Contribute to Sustainable Development?

When interviewees were asked to identify which emerging 4IR technologies could contribute to sustainable development for Commonwealth Member States and other countries, the prevalent response was: “All of them.” As one respondent put it, these technologies “optimise human behaviours and human capabilities.”

In elaborating upon their responses to the aforementioned question, respondents typically identified general and specific AI technologies that could contribute to sustainable development in COL and other countries across the globe. For instance, one respondent said:

The reality is that AI is going to change everything. There’s nothing in this world that will not be impacted by AI technology. And given the attention it’s been getting in the last few years — which translates into government research funding that leads to new ideas, entrepreneurship and start-up companies. In terms of 4IR technologies, I would say that AI is by far the most mature, is the one having the most current impact, and in the long run, the one that will have the deepest and most ramifications on society.

Specific AI technologies identified by the experts in response to this question included: autonomous vehicles and drones, XR technologies, machine learning and deep learning technologies, and intelligent tutors.

How Can These Technologies Be Used to Provide Services to Citizens?

One 4IR technology, blockchain, “has the potential to contribute to a number of the UN SDGs and engender widespread change within a number of established industries and practices” (Hughes et al., 2019, p. 114). In fact, blockchain is already impacting financial, commercial, educational, industrial and judiciary sectors (G. Chen et al., 2018, Hidayatno et al., 2019; Hughes et al., 2019; Muhuri et al., 2019; Stock et al., 2018). Briefly stated, a blockchain is an open ledger shared by all involved parties, which they access via public or private encryption keys. Blockchains reduce time delays, miscommunications and fraud, while eliminating third-party oversight. For instance, in a supply-chain system, a blockchain would hold all contracts, eliminating mistrust and confusion during the development, transfer and delivery of goods and payments. Blockchain GPS would facilitate transportation and tracking of goods. Contract deliverables, including payment for goods and services, would be immediately triggered upon completion of these contract specifications (Hughes et al., 2019). As Stock and colleagues (2018) explain:
Blockchain technologies are used for distributing data and for increasing security in supply and manufacturing process chains. These characteristics can be used for tracking sustainability related indicators such as child labour or the origin of resources and making them available to stakeholders and decision makers. Learnstruments and the application of ICT in manual working processes can provide digital information about working tasks and artefacts for increasing the learning effectivity of humans as well as for assisting the completion of complex working tasks which might lead to more ergonomic and safer working conditions. (p. 263)

Jia et al. (2019) discuss how smart buildings, cities and other infrastructures employ IoT technologies to help achieve the SDGs, pointing out that numerous companies, including Intel and IBM, are currently launching smart building products around the globe. Typical IoT technologies for smart infrastructures fit into five broad categories: devices/sensors, communication networks, cloud repositories/data processing, analytics, and actuators or user interfaces/services. To illustrate, smart building services may include:

- Occupant orientation and resource tracking (e.g., helping a new resident find their way in a building)
- Energy management
- Facility management (e.g., detection of malfunctions; timely repairs and maintenance)
- Indoor comfort enhancement
- Safety and health measures

For example, for SDG4, multiple systems will interact and share information to detect an individual’s learning needs, connect the learner to a tutor based on those needs, provide the learner with background information, monitor their progress, adapt the learning experience to the individual, connect the learner to the relevant evaluation system, and then inform the educational institution to certify the learner. These processes can be completed without human intervention.

One smart-building healthcare scenario that Jia and colleagues (2019) present is the use of small wearables attached to hospital patients’ clothing that would monitor and relay vital signs, alert healthcare professionals when needed, track patients and enable communication.

To enhance the SDGs, AI can also be used to manage complex systems by learning about situations, predicting events and the impacts of hypothetical scenarios, providing feedback, and in some cases, making decisions (Lou, 2018). For instance, the city of Hangzhou in China is leveraging the Alibaba-Cloud ET City brain to forecast traffic patterns, detect incidents, and optimise traffic flow (Lou, 2018).

Interviewees detailed a number of case studies in which 4IR technologies are currently being employed to facilitate the achievement of the SDGs. The first example, the “Smart Learning Partner,” derives from Beijing Normal University. Using an integrated learning management system and AI app, the Smart Learning Partner matches learners to appropriate tutors on demand. A second project, currently under development and funded by the Malaysia Research University Network (MRUN), engages the use of robotics to assist autistic children. The project considers how 4IR learning spaces, VR, AR, smart watches, and wearables may impact the lives of autistic learners.

Interviewees also presented cases in which UAVs and autonomous vehicles can prove invaluable. One wheelchair-bound interviewee shared their views on how liberating autonomous vehicles are for the disabled or those who are otherwise forbidden to drive, pointing out that blind people, for instance, can now possess the freedom to travel without human assistance. Other interviewees talked about how beneficial UAVs are for environmental monitoring, tourism and education, giving examples of how such technologies can be used to: (1) closely, yet safely and expeditiously explore and
capture vital data in remote or dangerous environments, such as active volcanoes and environmental disaster areas, (2) deliver medical supplies to remote or otherwise inaccessible locations, (3) swiftly, thoroughly and economically scrutinise agricultural crops and herd livestock without ground disturbance, and (4) securely observe potential terrorist or other criminal activity.

One interviewee described a project, PSET-Cloud, that JET Educational Services is developing for use in South Africa. In the interviewee’s own words, the idea is to create an interoperable and platform-based system for the post-school education and training (PSET) sector in South Africa that will allow more efficient data collection, collation, and use for government agencies, students, the labour market, and of course, researchers also as a kind of peripheral beneficiary.

Interviewees provided a number of examples where AI technologies can enhance inclusivity and empowerment for global citizens. To illustrate, one interviewee pointed out that the Internet represents only five percent of the world’s languages. This expert describes how one learning/neural network technology, natural language processing, offers an equitable solution, saying:

I think natural language processing is the crux of pretty much everything if we want to talk about equitable access, or worldwide or international equality in any way going forward through the fourth industrial revolution. So, I think these types of translation-based AIs and really anything that can support minority language speakers in accessing information is going to be the most helpful, to be honest.

According to a second interviewee, the employment of natural language processing also facilitates better communication between governments, other public institutions, and citizens, especially in countries where numerous languages are found. Finally, another interviewee envisioned how the integration of “holograms, drones and AR” could enable global citizens “to have better access to information and be able to be more informed about things and be able to participate more effectively.”

One pilot project in India is exploring ways in which AI can facilitate the prediction and diagnosis of prevalent diseases, such as heart ailments. Another project is focusing on the development of an AI app that can read and transform medical practitioners’ handwriting into various digital formats to facilitate the processing of medical prescriptions and other medical information. There are also chatbots being designed to help patients complete forms; others are employed to reduce patients’ anxiety. Global research projects could examine the viability of such initiatives for providing better health services to disadvantaged citizens around the world.

Unravelling the paradox between resource consumption and environmental sustainability is another area where global projects can offer assistance. To illustrate, AI-enhanced UAVs may be employed to gather data, assess environmental conditions, monitor agricultural production, and detect illegal activities, such as poaching and terrorism. Predictive modeling and rapid prototyping can then extrapolate the gathered information to provide potential future scenarios and products that further facilitate the selection of prudent sustainability options. Blockchain and GPS tracking will also offer solutions by facilitating the transparent, trustworthy and efficient development, transfer and delivery of goods, services and payments (G. Chen et al., 2018; Hughes et al., 2019; Muhuri et al., 2019; Stock et al., 2018).
CONCLUSION

What Role Can the 4IR and AI Play in the Implementation of Future Projects?

The greatest role that the 4IR — and AI, in particular — can play in the Commonwealth and global sustainable development projects is the enhancement of equity among global citizens. This includes not only minimising social and cultural biases, such as ethnic and gender prejudices, but also eroding other barriers that prevent equal access to technologies, employment opportunities and education. A prominent theme arising from this study is the pivotal function of education in fostering greater equality. Yet study results also underscore the urgent need to educate and support teachers, learners and other global citizens in the transition to the 4IR era and the related Education 4.0 paradigm shift. Future Commonwealth projects and other global initiatives could play a vital role in facilitating these transformations by offering educational stakeholders timely, inexpensive and easily accessible professional development and training resources, such as intelligent MOOCs and OER. Such resources would include the introduction to new pedagogies, coupled with case study examples of how these pedagogies are employed in traditional learning environments, as well as in “new, increasingly relevant, practical, and immersive learning environments” (Ally & Wark, 2019a; Grimus, 2020; Rizk, 2020). Other needed resources are educational packages aimed at developing: (1) essential numeracy, literacy and digital skills, (2) social, moral and critical thinking capacities, along with creative, problem-solving capacities, that engender emotional intelligence, flexibility and adaptability, and (3) lifelong learning opportunities (Ally & Wark, 2019a, 2019b; Aoki, 2020; Aziz Hussin, 2018; Brown & Keep, 2018; Butler-Adams, 2018; Gusmão Caiado et al., 2018; Lou, 2018; Mourtzis et al., 2018; Wark, 2018).

New learning contexts, such as holistic, immersive learning environments, MOOCs, and remote and virtual labs, have the ability to supersede the Education 3.0 barriers of time, place and space, offering learners the lifelong opportunity to apply theoretical knowledge to innovative ideas and products, while safely earning practical, real-world experience within their personal learning environments (Ally & Wark, 2019a, 2019b; Block et al., 2018; Grodotzki et al., 2018; Mavrikios et al., 2019; Mourtzis et al., 2018). The theoretical underpinnings of the Education 4.0 paradigm, its associated emerging pedagogies, and 4IR technologies such as AI, big data, ICT, IM, the IoS, the IoT, UAVs and XR, can be used in the Commonwealth and in other global projects to design, research, and evaluate these holistic, immersive Education 4.0 learning environments. These technologies can enable developing countries and marginalised citizens to gain access to these immersive learning environments.

Global initiatives may also capitalise on 4IR technologies that enhance equal access to education. For instance, one current project is testing the viability of high-altitude weather balloons for bringing mobile Internet services to rural Kenya (O’Grady, 2019). UAVs that are now being used to deliver emergency and medical supplies to remote, war-torn or otherwise inaccessible locations might also be employed as mobile Internet servers and transporters of other educational resources. MOOCs and OER are other technologies that global projects could use to facilitate greater access to education by the world’s citizens. Future projects should aim to promote equal access not only to 4IR technologies, but also to careers that involve the use of these technologies, especially AI, by girls and women (West et al., 2019).

Educational briefs, brochures and resources for government administrators, policy makers, educational
stakeholders and the general public that counter the myths and fears surrounding 4IR technologies are crucial. Interviews with experts clarified that teachers do not need to have advanced training in AI, for instance, but do require a basic understanding of AI to address, if not neutralise, their misunderstandings or lack of knowledge, and by association create an environment for their learners that embraces rather than excludes technology. Furthermore, government administrators, policy makers and educational stakeholders need exposure to examples of how 4IR technologies can be used for sustainable development in all sectors for the betterment of humankind and this planet. Future Commonwealth and other global activities could employ 4IR technologies to create and distribute educational packages that describe and exemplify how these technologies can be used for good.

Also, 4IR technologies such as AI, blockchain, IM, the IoT and the IoS can be incorporated into future Commonwealth and other global enterprises to track, monitor and suggest recommendations for improved services to Commonwealth and other global citizens. For example, AI and blockchain can be employed with respect to a particular educational initiative, to record, monitor, assess and make recommendations for improvement. The blockchain would offer an open, transparent, reliable and trustworthy ledger of interactions and transactions among all stakeholders, and how changes recommended by involved agents and AI affected the educational process and outcomes. AI would learn from these activities and thereby be able to offer better suggestions for future projects.

**What Role Can the 4IR and AI Play in Sustainable Development?**

The 4IR, AI and other 4IR technologies can be used to enhance cultural, social, economic and environmental sustainability for the Commonwealth and other countries of the world if governments, policy makers, business, industry and educational stakeholders, and global citizens have the access and know-how to employ these technologies. Donaires and colleagues (2018) identified three levels of societal effort to achieve sustainability: individual, organisational and worldwide. The most critical step towards sustainability is found at the individual level, where personal attitudes about the right to lead a self-centred lifestyle must be replaced by a willingness to embrace co-operative decision making and living, as well as an ethos of self-denial and self-sacrifice (de Raadt & de Raadt, 2014). The challenge faced at the organisational level is how to balance economic demands against internal social and environmental costs when developing a systematic approach to sustainability (Donaires et al., 2018). The dilemma at the worldwide level is how to measure, monitor and assess what progress is being made towards global sustainability (Donaires et al., 2018; Schwaninger, 2015; UNESCO, 2019b).

Global projects must invest in initiatives that incorporate neural networks and natural language processing so that global citizens of all languages can communicate with each other. This would greatly benefit countries such as India, where current levels of domestic mass migration of poverty-stricken citizens are hampered by the inability of social service systems to process documents or communicate with the needy due to language restrictions (Hughes et al., 2019).

In addition, AI and other 4IR technologies must be employed to increase equality among global citizens as the world enters the 4IR era. The primary key to achieving the SDGs is the adequate, relevant education of all the world’s citizens. This means that future global projects need to support research, innovation, financial initiatives and other incentives aimed at providing equitable, affordable access to 4IR technologies and to the Education 4.0 milieu that citizens need to survive and flourish in harmony with the environment as the 4IR era unfolds.
4IR Technologies for Sustainable Development: Challenges

Although 4IR technologies are being used in many sectors of society, there are a number of challenges to implementing 4IR technologies for sustainable development. For example, although natural language processing and translation applications have the potential to significantly impact the lives of many minorities by enabling large-scale interaction and access to global resources, such technologies are not readily available to the world in general. Perhaps the most critical challenge to achieving the SDGs lies in determining how to employ 4IR technologies to decrease the digital, economic, social and environmental divides — not only between developed and developing countries, but also between the wealthiest and the poorest citizens in all countries (Nexplo, 2018). The rapid emergence and obsolescence of technologies compounds issues of affordability and access to 4IR technologies that facilitate the attainment of the SDGs.

The various 4IR technologies are already being used in different sectors of society, and their wider use in the education sector is on the horizon (Bryant et al., 2020). The choice about participating in this new reality will be limited, and the reluctant risk being left behind.

Moving Boldly Ahead in the Fourth Industrial Revolution

The use of 4IR technologies is increasing at a fast pace. It is impacting all segments of society, and it is here to stay. Countries have to embrace technologies powering the revolution, remaining mindful of the fact that several challenges must be overcome if they wish to use it for achieving their development objectives. Some of the challenges include major deficits in the areas of infrastructure, skills, innovation, institutional frameworks and regulatory environments. Despite all the above challenges, thanks to the agility of the private sector, coupled with the responsiveness of the public sector in select countries, 4IR technologies are already being adopted in a few developing countries, with varying results. The education sector has to catch up with the private sector, or the private sector may move into the education business. Time is of the essence for developing countries (Adhikari, 2020).

Emerging digital technologies, such as computer hardware, software, sensors, machine learning, AI, the IoT, robotics, and big data, will converge to create cyber-physical systems that will transform how we learn, how we work, how we live our lives, how factories are operated, how manufacturing processes are controlled, how healthcare and transport services are rendered, and what kind of consumer markets can be created (Pollitzer, 2019). Recently, the way education is designed and delivered has changed dramatically as a result of the 2020 coronavirus pandemic. Education has shifted to an online format that is learner centred. The use of AI can personalise learning for individual learners, simulating intelligent tutors to compensate for the shortage of teachers. According to UNESCO (UNESCO Institute for Statistics, 2016), the world needs 69 million teachers to achieve SDG4. With the shortage of teachers in some developing countries, having intelligent tutors (i.e., technology-enhanced teaching, or TET) could help to address this shortage. It is better to have an “intelligent tutor” helping students rather than no teacher at all.

Educating citizens around the world will be the key to help achieve the SDGs. Education systems will need to provide education for all (Doucet & Evers, 2018). Education will become self-organising; technology will play a major role in instructional delivery and in providing support to learners (Mitra, 2014, 2019). Learning will move toward individualisation and learner-centredness due to 4IR technologies such as AI, learning analytics, and the IoT (Chai & Kong, 2017; Popenici & Kerr, 2017). The 4IR era will dramatically change the role of teachers, who will become “4IR”
or “digital” teachers, using deep-learning technologies such as AI, robotics, big data and the IoT (Ally, 2019; Bryant et al., 2020). The World Economic Forum (2017) foresees that teachers will need to adopt AI and robotics to teach in the 4IR. The “AI divide” and “4IR divide” will need to be bridged so that teachers and learners can be ready for the 4IR. In addition, education will play an important role in assisting the world with transitioning into the 4IR to achieve the SDGs by 2030. This will require a new lifelong, learner-centred educational paradigm, and learning environments that foster critical thinking, innovation, moral judgment, social inclusion and ecological sustainability (Aoki, 2020). Teaching factories, AI, blended and mobile learning, and machine learning all hold promise for educating citizens to help achieve the SDGs.

The lack of trained teachers and the poor condition of schools in many parts of the world are jeopardising the prospects for quality education for all (United Nations Economic and Social Council, 2017). The shortages of teachers and schools have been issues for many years. 4IR technologies have the potential to take education to students regardless of location and status, and develop intelligent teaching systems to tutor individual students. Kyllönen (2019), when rhetorically asking about the future of schools and societies, responded, “It is impossible to predict — but we can build it! There are problems and challenges that must be conquered — but at the same time, there are more opportunities and underutilised resources (witness the sharing economy) in our communities than ever before” (p. 334). The opportunity for education for sustainable development and to achieve the SDGs is the use of 4IR technologies, which are underutilised in education when compared to other sectors in society.

The UN 2030 SDGs are based upon notions of inclusive economic and social development, security and peace, and environmental sustainability (Habinak, 2019; Rosa, 2017). With careful planning and thoughtful implementation, 4IR technologies can help humankind achieve these goals. The reviewed literature indicates that one of the most significant contributions of 4IR technologies is transparent management of sustainable supply chains for the distribution of medical, food and water resources at individual, national and international levels, yielding a global economy that enhances sustainability for all.

During an interview, Audrey Azoulay, the Director-General of UNESCO, commented:

In general, AI can be a fantastic opportunity to achieve the goals set by the 2030 Agenda, but that means addressing the ethical issues it presents, without further delay. An opportunity, because its applications can help us to advance more rapidly towards the achievement of the Sustainable Development Goals (SDGs) — by allowing better risk assessment; enabling more accurate forecasting and faster knowledge-sharing; by offering innovative solutions in the fields of education, health, ecology, urbanism and the creative industries; and by improving standards of living and our daily well-being. (p. 37)

Vinuesa et al. (2020) claim no study has been done to examine the merits of AI to inform the SDGs, despite its untold potential. All sectors of society need to come together in research and development on the use of 4IR technologies for education and sustainable development.

There are many good ideas about how the 4IR can help with sustainable development, but there is an urgent need to put these ideas into practice to benefit humankind.
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APPENDIX A — INTERVIEW QUESTIONS

The Fourth Industrial Revolution, Artificial Intelligence and Emerging Technologies: Sustainable Development and New Literacy Skills for Educators and Learners

Thank you for sharing your insights and experiences on the Fourth Industrial Revolution (4IR; defined as a digital revolution combining physical, digital and biological facets that are impacting the world), emerging technologies, and the competency skills needed by educators to help global countries and citizens realise improved economic, social, cultural and environmental independence and sustainability. (For the purpose of this study, sustainable development is viewed as development that improves the lives of citizens while living in harmony with the environment.) Some examples of 4IR technologies include: robotics; artificial intelligence (AI); autonomous vehicles; mobile and ubiquitous computing; analytics; virtual, augmented and mixed reality; Internet of Things; and machine learning.

The following script will be read during the recorded interview.

QUESTIONS

A. BACKGROUND INFORMATION

1. What employment sector(s) have you worked in (i.e., business/industry, academia, government, civil service)?

2. How long have you worked in this sector (or these sectors)?

3. Could you please describe your educational and experiential background in relation to:
   a. The Fourth Industrial Revolution (4IR)?
   b. The design, development, research and/or use of emergent 4IR technologies?
   c. Teaching others how to use emergent 4IR technologies?

4. Is there anything else that you would like to say about your background in relation to the 4IR and emergent 4IR technologies?

B. THE ROLE OF THE 4IR AND EMERGENT 4IR TECHNOLOGIES IN EDUCATION AND SUSTAINABLE DEVELOPMENT

5. Could you please list emerging artificial intelligence (AI) and other emerging 4IR technologies that you are aware of?
6. a. Which of the technologies listed in B5 above do you think could contribute to sustainable cultural, social, economic and/or environmental development in countries?

   b. How might each of these technologies contribute to sustainable development in cultural, social, economic and/or environmental areas?

7. How might each of these technologies be used to educate global citizens?

8. How might these technologies be used to provide other services to global citizens?

C. FINAL COMMENTS AND RESOURCE RECOMMENDATIONS

9. What final comments would you like to make regarding the role that 4IR, AI and other emerging technologies may play in global sustainable development, and equitable, high-quality education for global citizens?

10. Do you have any publications, reports or links to web resources to recommend or share that would help to further inform our investigation in this project?

Please note: You will receive a rough draft transcription of this interview via email attachment. Please edit, verify and return the copy of this interview as your official interview transcript via email attachment. Once received, this transcription indicates that you are providing consent for inclusion of these data in the study.

We would like to thank you for this valuable information and your time commitment to this project.

Sincerely,
Dr. Mohamed Ally (mohameda@athabascau.ca)
Dr. Norine Wark (norinewark@athabascau.ca)
Athabasca University, Canada

This study has been approved by the Research Ethics Board at Athabasca University. Should you have any questions or concerns regarding your treatment as a participant in this study, you may contact:

The Office of Research Ethics, Athabasca University at 1-800-788-9041, ext. 6718 or via e-mail to rebsec@athabascau.ca.