Learning for Sustainable Development in the Fourth Industrial Revolution

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Abstract

There is a growing sense of urgency to adopt Fourth Industrial Revolution (4IR) technologies, such as artificial intelligence (AI), robotics, the Internet of Things (IoT), and data analytics in education. Yet there appears to be no clear direction on what technologies should be adopted, how they should be integrated, or what effect their inclusion may have on the field of education or on learners. A research project exploring various 4IR technologies, and the benefits and challenges of employing these technologies for global sustainable development and education is underway. As part of the project, this paper presents initial findings from a thematic review of 28 academic peer-reviewed journal articles from 2017 to 2019 on the use of 4IR technologies for attaining the United Nations' 2030 Sustainable Development Goals (SDGs) and in education around the world. Findings include examples on the beneficial uses and implementation challenges of 4IR technologies for sustainable development and education. The aim is to develop an informed, collective understanding of the benefits, challenges, and other issues arising from adoption of 4IR technologies for achieving the SDGs, especially in relation to education. Recommendations for future projects and research initiatives are also considered.

Keywords: Artificial Intelligence, Commonwealth Countries and Citizens, Fourth Industrial Revolution, Machine Learning, Sustainable Development, Technology

Introduction

As the world moves into the *Fourth Industrial Revolution* (4IR; defined as a digital revolution combining the physical, digital, and biological facets that are impacting the world), there is a sense of urgency for countries to use 4IR technologies for sustainable development to provide services to improve the quality of life for all citizens. The World Economic Forum (2017) declares 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. According to Schwab (2019), the 4IR is more than technological advancement; it is an upheaval that is impacting different sectors of society.

The World Commission on Environment and Development (1987) defines sustainable development as development that meets the needs of the present without compromising the ability of future generations to meet their own needs. This definition is too general to guide research and development. A more workable definition considers development that improves the lives of citizens while living in harmony with the environment. The 4IR is changing the world because of new technologies that blend the physical, digital, and biological worlds, and dynamically impact disciplines, economies, and industries (Schwab, 2016). A merger of these latter notions yields a definition for sustainable development in the 4IR, which is "the use of technologies to combine the physical, digital, and biological worlds to improve the lives of citizens living in harmony with the environment."

Literature Review

The United Nations Sustainable Development 2030 Agenda contains 17 sustainable development goals (SDGs) and 169 targets intended to help guide all sectors of society to improve lives and to make the world a more comfortable place to live and work (Pollitzer, 2018; Rosa, 2017; United Nations, 2015). One important SDG for education is Goal 4: "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. Malaysia, for instance, has identified initiatives to use 4IR technologies for learning and development (Ally, Norazah, & Norman, 2019). Achieving the SDGs will be challenging. The education system has to provide education for all (Doucet & Evers, 2018). Education will become self-organizing; technology will play a major role in instructional delivery and in providing support to learners (Mitra, 2014). Learning will move toward individualization and learner-centeredness, due to 4IR technologies such as artificial intelligence (AI), learning analytics, and the Internet of Things (IoT; Chai & Kong, 2017; Mitra, 2014; 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, IoT, etc. (Ally, 2019). The World Economic Forum (2017) foresees that teachers will need 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. Organizations such as the Commonwealth of Learning (COL) are helping countries to achieve sustainable development by providing learning opportunities to citizens. COL is emphasizing “learning for sustainable development,” using emerging technologies for online and distance education for lifelong learning that leads to sustainable development (COL, 2015).

Methodology

This paper reports on initial findings from journal articles reviewed for two research projects that examine the relationship between 4IR, sustainable development, and education. The following sub-sections present the search procedures and selection results of this process.

Selection Procedure for Articles

A university meta-database search engine was employed to identify potential 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 “technology in education,” (4) “fourth industrial revolution” AND “sustainable development goals” AND education AND technology, (5) “Artificial intelligence” AND “personal* learning,” and (6) “Education 4.0.” (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 an English-language peer-reviewed journal article located in one of the university-subscribed or open access journal databases, and published between January 1, 2017 and December 31, 2019. Any publication that did not fit these criteria was excluded from the study.

Number of studies reviewed. 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 and abstracts. The other researcher then analyzed the full texts of the promising articles for their ability to answer the research questions posed in the study. The keyword searches produced 461 potential articles with 87 replicates, yielding a total of 374 unique titles. (Table 1 lists databases that generated five or more articles in the initial search.) A full-text analysis of these articles was then conducted to determine what articles addressed the research questions at hand, yielding a final total of 98 articles for the study.

Table 1

Number of Journal Articles Identified by Keywords by Journal Database

Journal Database	Number of Journal Titles
ScienceDirect	195
Academic Search Complete	96
Business Source Complete	51
Academic OneFile	30
SocINDEX with full text	19
Emerald Insight	11
Expanded Academic ASAP	10
Directory of Open Access Journals	9
General OneFile	7
Communication & Mass Media Complete	5
InfoTrac Computer Database	5

Note: Only databases yielding five or more journal titles are included.

Results and Discussion

This section is based upon a thematic review of 28 of the final articles included in the study. These 28 articles (listed with an asterisk in the reference section) were chosen because they reflected the Ninth Pan-Commonwealth Forum (PCF9) conference theme, "Innovations for Quality Education and Lifelong Learning" and sub-theme, "Technology." This section is organized into two major sub-sections: "Use of 4IR technologies for sustainable development," and "Use of 4IR technologies in learning for sustainable development."

Use of 4IR Technologies for Sustainable Development

A complete list of 4IR technologies mentioned in the 28 articles includes: AI, augmented and virtual reality (AR and VR), Big Data, blockchain, Cloud computing/technology, Cyber-Physical Systems, Information and Communication Technologies (ICTs), Internet of Services (IoS), Interoperability, IoT, mobile learning, networking, Smart Factory, smart sensors, and Teaching Factories.

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). Briefly stated, blockchain is an open ledger shared by all involved parties, which they access via public and 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).

Hughes et al. (2019) offer a number of scenarios where blockchain technology could promote SDGs. For instance, a blockchain smart food card could be employed 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 programs. This would reduce reliance on human resources, improve efficient and effective delivery of services, as well as provide reliability, verifiability, transparency, and improved trust among all parties.

Jia, Komeily, Wang, and Srinivasan (2019) discuss how smart buildings, cities, and other infrastructures employ IoT technologies to help achieve 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.

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

Challenges of using technology for sustainable development. The most significant challenges in using 4IR technologies to achieve SDGs are access to, and education on how to innovatively implement these technologies. Achieving SDGs is a struggle for developing countries battling with overpopulation, pollution, poverty, illness, conflict, corruption, and political upheaval (Fayomi, Okokpujie, Fayom, & Okolie, 2019). In some countries where the industrial level of 4IR technology integration is categorized as non-existent (Hidayatno, et al., 2019), attaining SDGs by 2030 seems inconceivable. In 2016, renewable energies constituted 19.2% of global energy consumption (US Energy Information Administration, 2016). Integration of renewable energies into digitally-controlled power systems would significantly enhance SDGs. The primary barriers to implementation of renewable energies are bureaucracy and corruption (Gusmão Caiado et al., 2018; Mboumboue & Njomo, 2016). Clearly, developed and developing nations must embrace the shared vision encapsulated within the SDGs and work together to achieve these goals (Fayomi et al., 2019; Gusmão Caiado et al., 2018; Hidayatno, 2019). "(M)ega-shifts in datification, robotizaton, and cognificaton" (Wan Chik & Arokiasamy, 2019, p. 489) also require transformation of the current educational system (Morgan, 2017).

Use of 4IR Technologies in Learning for Sustainable Development

Realizing SDGs necessitates the development of 4IR technology and innovation cultures, training, and knowledge (Chen et al., 2018; Hariharasudan & Kot, 2018), which are hallmarks of Education 4.0.

Education 4.0. Education 4.0 merges industry and education by providing real and virtual world learning experiences within authentic contexts, and prepares learners for a mixed reality future (Grodotzki et al., 2018). Education 4.0 aims to: develop numeracy, literacy, digital, social, critical thinking, moral, and creative, problem-solving capacities; nurture emotional intelligence, flexibility, and adaptability; and foster the mindset of lifelong learning (Aziz Hussin, 2018; Brown & Keep, 2018; Butler-Adams, 2018, Gusmão Caiado et al., 2018; Lou, 2018; Mourtzis et al., 2018). The curriculum is non-linear, interdisciplinary, de-colonized, learner-centered, personalized, and of international quality (Aziz Hussin, 2018; Morgan, 2017; Mourtzis et al., 2018). As such, education 4.0 reflects a paradigm shift from the previous industrial revolution educational paradigm, employing emerging pedagogies, such as heutagogy, paragogy, and cybergogy (Wan Chik & Arokiasamy, 2019) within new, increasingly relevant, practical, and immersive learning environments.

Holistic immersive learning environments. Holistic immersive learning environments merge research, education, and innovation, providing learners with the opportunity to apply theoretical knowledge and to experiment with innovative ideas using ICTs and VR technologies. One example is Teaching Factories, where workers and managers benefit from the latest theory, research, and technology advances that learners bring with them, while learners discover the practical benefits and challenges of implementing these concepts and technologies in real industry settings. Use of ICTs and VR technologies enable learners to "visit" industrial settings without disrupting workflows or encountering safety issues (Block, Kreimeier, & Kuhlenkötter, 2018; Mavrikios et al., 2019; Mourtzis et al., 2018).

Examples of beneficial use of 4IR technologies for education and learning. Mavrikios et al. (2019) used holograms, finger tracking, and mobile technologies to facilitate interaction with educational content in a Teaching Factory. 3D holograms were simultaneously manipulated and viewed by multiple people from various angles in the factory and classroom setting as the task at hand was discussed together. Viewers could "explode" any component to see the parts that constituted that component. Display annotations, other functionalities, and content were also accessible via users' personal mobile devices. In a second example, Massive-Open-Online-Course (MOOC), remote labs, virtual representations of the labs, AR, and additive manufacturing technologies allowed learners to visually explore and test complex engineering processes from a distance (Grodotzki et al., 2018). Adopting a blended learning approach and use of personal mobile devices, a flipped classroom approach tasked learners with absorbing theoretical content outside of the class setting, freeing them to engage in interactive learning during class, while enabling them to set personal learning goals and develop time-management skills (Aziz Hussin, 2018). A final example incorporates "machine learning" (using algorithms to program software) to predict student performance, assess learners fairly, improve retention, and provide administrative duties (Kučak, Juričić, & Đambić, 2018). Machine learning can eliminate standardized testing and offer personalized learning, providing "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).

Challenges when using 4IR technologies for education and learning. The 4IR requires significantly more investment in basic education and Education 4.0, especially within developing countries (Brown & Keep, 2018; Fayomi et al., 2019; Gusmão Caiado et al., 2018; Habinak et al., 2019). Brown and Keep (2018) point out that technology is emerging so rapidly that educational systems, institutions, educators, and other resources cannot keep pace. Curricula and pedagogical approaches that focus upon specific technological skills are inadequate. Yet providing basic numeracy and literacy education in native languages still remains a challenge in many countries. Habinak et al. (2018) observe that "…no strategies have been adopted to make the education system ready respond to the new trends" (p. 48), concluding that the 4IR will lead to the demise of the traditional educational paradigm.

Conclusion

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.

A second prevalent theme arising from the literature is the pivotal role of education in assisting the world for transition into the 4IR. This requires a new lifelong, learner-centered educational paradigm and learning environments that foster critical thinking, innovation, moral judgment, social inclusion, and ecological sustainability. Teaching Factories, AI, blended and mobile learning, and machine learning all hold promise for reaching such Education 4.0 goals.

Recommendations for Projects

Chen et al. (2018) describe the holistic innovation model employed by the Chinese government since 1978, which has seen this country emerge as a new world leader. The model is now being used to implement SDG initiatives. One project could involve adaptation of this iterative, all-inclusive multi-level model for integrating digital skills and technologies in an educational system or institutional setting. A second project could involve the development of an iterative Education 4.0 framework that includes operational definitions, reliable indicators, and timestamps for attaining educational SDGs, including digital literacies. Perhaps part of this project would involve merging heutagogical, paragogical, and cybergogical approaches within a learner-centered paradigm. Education 4.0 initiatives that provide open access to innovative, adaptable guidelines, services, and resources that meet the dynamic needs of individual learners in diverse learning environments with the support of 4IR technologies are also recommended.

Recommendations for Research

Synthesis of reviewed literature indicates that there is much hype about how 4IR technologies are transforming every sector of global society, but little research has been done on the short- or long-term consequences of applying such technologies in practice. For instance, while blockchain technology literature is becoming publicly-accessible, most corporations have not moved beyond feasibility studies due to cost-versus-benefit concerns and legal issues (Hughes et al., 2019). Future research should include case studies, large sample surveys, and mixed methods research across all sectors, cultures, and geographic locations to develop a more comprehensive, yet global perspective on access and usage patterns, as well as the benefits and challenges of implementing 4IR technologies for synergistically attaining SDGs. In addition, education and other disciplines must conduct research and work together to develop learning systems using AI, robots, and other technologies to educate global citizens so that they can use 4IR technologies for sustainable development.

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