FOURTH INDUSTRIAL REVOLUTION: OPPORTUNITIES AND CHALLENGES ON HIGHER EDUCATION INSTITUTIONS (HEIs) TOWARDS 2030 SUSTAINABLE DEVELOPMENT GOALS (SDGs) AGENDA

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Abstract : The Industrial Revolution 4.0 or popularly known as "Industry 4.0" "4IR", or "FIRe" is considered as one of the vital catalysts in the pursuit of the United Nation's sustainable development goals (SDGs). It also brings prospects to enhance the role of higher education institutions (HEIs) in providing innovative academic and life-long learning programs that will improve the competencies and skills of graduates to respond proactively to the impacts brought by today's technological advancement. In particular, this paper provides an intensive review of literature available, and the author's point of view which provide a better understanding of the significant impacts of Industry 4.0 to civil engineering and environmental professions as well as informing these professionals to continually invest in lifelong learning - to become more relevant and indispensable workforce in the 21st century.

Key words : Industry 4.0, sustainable development goals, higher education institutions, technological advancement

1 INTRODUCTION

The fast changing technological developments have affected people's daily activities – work, play, study, eat, sleep or shop (TESDA, 2016). WEF (2016) as cited by Dadios et al (2018) states that these technological advancements such as artificial intelligence, internet of things (IoT), robotics, autonomous vehicles, drones, nanotechnology, 3D printing, biotechnology and genetics, and virtual realities have steered in the Fourth Industrial Revolution (FIRe) or commonly known as "Industry 4.0" or "4IR". Consequently, these technological advancements are expected to change production, consumption and employment that all sectors of society (private and public sectors, including individuals) require their proactive involvement or collaboration as well as adaptation to this rapid and disruptive technological change of the FIRe. The effectiveness of the adaptation by these major players depend on the timeliness of its preparation, implementation, and shared approaches. Overall, these technological developments will shape the social, economic and political outcomes of a nation (Dadios et al, 2018; NSTF, 2018).

According to Mohieldin (2017), these new technologies is enabling inclusive growth, particularly these digital solutions and connectivity are key to accelerate and achieve the sustainable development goals (SDGs). TW12050 (2018) identified the correlations or linkages between sustainability and digital transformations. It is viewed that this transformation towards sustainability must be linked with the digital transformation by gearing the opportunities and dynamics of the digital revolution to the goals of the 2030 Agenda. These technologies can make a constructive contribution to the social, economic and environmental challenges; and can bring to support the ambitions of the 2030 Agenda for Sustainable Development (UNDP, 2018). Moreover, this digital revolution also brings prospects to enhance the role of higher education institutions (HEIs) in providing innovative academic and life-long learning programs that will improve the competencies and skills of graduates to respond proactively to the impacts brought by FIRe. Higher education in Industry 4.0 requires much more innovation, research and interdisciplinary teaching which can transform society for brighter future.

2 OBJECTIVES

This paper focuses on the relationship between FIRe and higher education, and how the former will be successfully integrated in higher educational system; consequently to advance the human capital in developing countries like the Philippines to address local challenges and opportunities to improve the engineering and environmental education that are capable to adapt to Industry 4.0 economy. Moreover, this paper identifies the impacts of FIRe towards achieving some of the SDGs that also challenge civil engineering and environmental professionals who are "educators" in higher education institutions (HEIs) to become more responsive for preparing graduates in facing the demands that the labor market offers.

3 METHODOLOGY

To achieve the objectives, an intensive review of literature was conducted. The author's point of view based on his expertise and experience was incorporated in the paper to have a better understanding of the significant impacts of Industry 4.0 in civil engineering and environmental education and professional practice as well as to inform these professionals to continually invest in lifelong learning - becoming more relevant and indispensable workforce in the 21st century.

4 DISCUSSIONS

4.1 Background in the Emergence of Industrial Revolutions

According to Philbecek & Davis (2018), industrial revolutions are times of technological change with broader social transformation. These periods are more than the development and introduction of new technologies, but rather these periods lead to the shift of entire systems of power. Industrial revolutions are novel ways of perceiving the world that cause change in economic systems and social structures (Eden, 2018). ***Table 1*** summarizes these industrial revolutions – from the emergence of the first revolution in the 18th century to the fourth industrial revolution commonly known as "FIRe", "4IR" or Industry 4.0 (Alalou et al, 2018; Dadios et al, 2018; Philbecek & Davis, 2018; Eden, 2018; Kazancoglu & Ozkan-Ozen, 2017; Van Dam, 2017; Schwab, 2015).

Table 1. Emergence of Industrial Revolutions

Revolution/Period	Key Concept/Outcome
1st Industrialization (1760-1840; Late 18th –Early 19th century)	Mechanization, Water and Steam Engine/Power *(Machine replace animal and manual labor)* Improvement in standard of living (including transportation, communication and banking); increase in manufactured goods; the growth of industries in coal, iron and textile
2nd Industrialization (1870-1914; Late 19th -Mid 20th century)	Mass production, assembly line and electricity *(Mass manufacturing, machines and processes)* Electric railroad and electric cars; radio communications; radio wave transmission; inventions of elevator, telephone, refrigerator, typewriter, phonograph, washing machine and diesel engine
3rd Industrialization (1950s-1970s); Second half of 20th – early 21st Century)	Computer, Automation and Information Technology *(Digital revolution and globalization; analog to digital technology; worldwide web)* Computer, digital mobile phones, and the internet; digital communication (cellular phones), digital camera, CD-ROM, including automated teller machines, industrial robots, electronic bulletin boards, and video games
4th Industrialization (Early 21st Century - Present)	Cyber Physical Systems *(Automation/robotics, artificial intelligence, analytics, Internet of Things)* Self-driving cars, drones, virtual realities, software that translates, invests, analyze and identify; social media; nanotechnology

Eden (2018) summarizes the definitions and key features of FIRe. Firstly, FIRe is the "digital economy" being characterized by a fusion of technologies and skills (Alaloul et al, 2018) that is blurring the lines between the physical, digital and biological scopes (Schwab, 2015). Secondly, it comprised of markets based on digital technologies that facilitate the trade of goods and services through e-commerce. Thirdly, as social and economic activities that enable by internet or mobile technology platforms that provide 24/7 access and support multiple, virtual and connected networks. Fourthly, it is one of the key "winds of change" that replacing traditional forms of multinational enterprises fueled by several disruptive technologies as presented in ***Table 2*** (Dadios et al 2018; UNDP, 2018).

Table 2. Disruptive Technologies

Technology	Concept/Definition
Internet of Things (IoT)	It refers to the fusion of Internet connectivity and association of electronic devices, vehicles, structures, buildings, and other devices with electronics, software, sensors, actuators, and communication capabilities which equip the said items to send, transmit and process information with less human interventions. It also enables objects to be monitored and controlled remotely to increase efficiency, accuracy and productivity. Examples: smart power grids, virtual power plants, intelligent transportation systems, and automated homes (component of smart cities).
Big Data	It refers to the generation and computation of very large datasets. A popular definition refers to "three Vs" – volume (scale), velocity (streams across time) and variety (complex); including variability and complexity. This data is exhaust from electronic devices, social media, search engines, sensors and tracking devices (GPS) Making use of this data involves descriptive analytics (e.g., getting customer profiles and behavior from social media and customer transaction databases), predictive analytics (i.e., forecasting future events) and even prescriptive analytics (using simulation and optimization methods) that extract value from digital data.
Robotics and Automation	It is a multi-disciplinary area of engineering and science involving the fields of mechanical, electrical, computer science, and other engineering-based fields. It is refers to the science of design, construction, operation, and implementation of robots, as well as computer systems for control, feedback, and information processing. Robotics aims to replace humans in tedious and hazardous tasks which is more acceptable in human environment and performing repetitive human tasks. Humanoid robots replicate walking patterns of humans, lifting objects, speech, and cognitive skills; and it is also mimic behavior and movements observed in nature especially animal movements.
Artificial Intelligence (AI)/ Machine intelligence	These are computer-based applications that carry out functions typically associated with humans such as visual perception, decision-making, and speech recognition. It is the programmed reasoning and thinking skills applied to machines to mimic human or animal intelligence. AI is also defined in the computer science discipline as the design and implementation of intelligent agents (units that senses the environment and create decisions). It deals with the study of humans' ability to learn and solve problems being referred to as cognitive (mental) skills.

Furthermore, Eden (2018) explains that FIRe is distinct from the 3rd Revolution in terms of velocity, scope (breadth and depth) and systems impacts (Van Dam, 2017). European Commission (EC) as cited by Eden (2018), it has three key features, namely: mobility, network effects, and data usage which somehow influence the domestic and international markets. On the other hand, Kudriashov et al (2016) as cited by Alaloul et al (2018), FIRe is the "*integration of complex physical machinery and devices with networked sensors and software…for better business and societal outcomes…or new level of value chain organization and management across the lifecycle of products*." Alaloul et al (2018) identified CPS (cyber physical system), the internet of things (IoT), the internet of services (IoS), and the intelligent units are the main ingredients of FIRe. On the other hand, Hermann & Otto (2016) as cited by Snudden (2019), FIRe fits into the design principles of inter-connectivity, information transparency, technical assistance and decentralized decisions or it is synonymous with technical developments in manufacturing (Snudden, 2019). Thus, FIRe is impacting all disciplines, industries, and economies and even challenging ideas about what it means to be a human being (World Economic Forum, 2019).

4.2 Fourth Industrial Revolution and Sustainable Development Goals

In general, the digital revolution is reshaping work, leisure, behavior, education, and governance which can raise labor, energy, resource, and carbon productivity, lower production costs, expand access, dematerialize production, improve matching in markets, enable the use of big data, and make public services more readily available (TWI2050, 2018). Particularly, this digital revolution has brought many private benefits. As compiled in 2015, the data showed that: 8.8 billion youtube videos watched ; 2.3 billions gigabytes of web traffic; 803 million tweets; 4.2 billion google searches; 207 billion emails sent; 186 million Instagram photos shared; 152 million skype calls; and 36 million amazon purchases (Mohieldin, 2017). These digital solutions associated by FIRe are key to accelerate the achievement of the 17 SDGs particularly SDG#3: good health, SDG#4: quality education, SDG#7: renewal energy, SDG#8: good jobs and economic growth SDG#9: innovation and infrastructure (Maddah, 2016; Mohieldin, 2017). These technological developments have also bring substantial impacts to SDG#5: gender equality and SDG#10: reduced inequalities and SDG#11: sustainable cities and communities (Khasru, n.d.).

The UNDP Report (2018) provides excellent discussions on how FIRe will deeply affect communities in the Asia-Pacific region, particularly on how it will transform existing systems of production, management, and governance. The UNDP report also focuses on how countries embrace and adapt to the coming technological changes towards meeting the 2030 Agenda for Sustainable Development and achieve the 17 SDGs. Specifically, the report outlines the potential negative and positive scenarios and impacts towards realization of the SDGs by 2030 in terms of policy instruments and directions across the three main domains: social, economic and environmental, ensuring the FIRe's disruptive technologies facilitate rather than threaten the progress to the 17 SDGs. **Table 3** lists down both the negative (risks/ threats) and positive (opportunities) scenarios and impacts on FIRe.

According to Mohieldin (2017), 50% of the world's population is not benefiting from the digital economy, with more complex and violent conflicts are being experienced with displaced population and inequalities within countries. Further, the negative externalities from FIRe include the following: (a) Machines unable to follow ethical guidelines; (b) Gap in digital literacy; (c) Expensive healthcare services and products; (d) Low levels of internet penetration and usage; (e) Job loss from automation and artificial intelligence (Khasru, n.d.).

On the positive side, there are opportunities that FIRe can offer for transformation towards a sustainable path through following ways: (a) improve coordination with timely and effective policy instruments, (b) localize implementation and engage/mobilize local communities, (c) efficient resource allocation, (d) strong government and private sector involvement, (e) available quality data, and (f) cross-institutional collaboration (Mohieldin, 2017).

Table 3. Threats and Opportunities on FIRe Technologies

SDG	Risk/Threat	Opportunity
SDG#1 No poverty	Increased unemployment; end of export-led manufacturing model; reduced tax base	More efficient welfare through digital ID; AI and big data-enabled financial technology (fin-tech); and new livelihoods in the gig economy (short-term service contract and freelance work)
SDG#2 Zero hunger	Lower disposable income for food purchases; reverse migration to food-insecure rural areas; micronutrient-deficient diets.	AI and big data-driven food supply chains optimization; improved manufactured food quality through sensors; and yield improvement through precision agriculture.
SDG#3 Good health and well being	Health spending constraints; lack of safeguards in gig-economy; job insecurity	Advanced health diagnostics; improved access to care through telemedicine; blockchain (digital ledger of transactions) and AI-optimized patient data
SDG#4 Quality Education	Obsolete educational curricula; reduced public spending on education; widening gap between high and low-skilled	Low cost e-learning tools; Speech recognition for learning; AI-based marking optimizes teacher time allocation.
SDG#5 Gender Equality	Greater gender pay imbalance in STEM; reduced women employment in BPO and retail; algorithm-driven decisions bias against women.	Women opportunity in automation proof sectors (e.g care economy & tourism); reduced decisionmaker bias in recruitment or finance through AI-powered selection software.
SDG#8 Decent work and economic growth	Resurgence of informal sector; loss of export-led manufacturing model; regionalization of supply chains.	Creation of new, improved livelihoods; reinvigoration of rural areas through internet-enabled entrepreneurship

SDG#9 Industry innovation and infrastructure	Decline of the BPO (business process outsourcing) sector; decline of developing economy Technological innovation; polarized industrialization	Benefits of IoT encourage ICT (information and communication technology) infrastructure investment (e.g 4G/5G); emergence of new innovation champions in middle income.
SDG#10 Reduced inequalities	Racial and ethnic bias from badly designed AI; wealth polarization away from labor; Higher wages for STEM-trained middle classes.	Women excel in rising sectors of creative industries and e-commerce; Internet inclusion gives discriminated groups more independent means of income
SDG#16 Peace, justice and strong institutions	Social media bots (device or software) generate misinformation; increased cyberterrorism vulnerability; AI-based surveillance targets minorities.	Blockchain powered citizen data management; human rights enforcement through social media listening.

The World Economic Forum Report (2017) explained that to become sustainable, emerging cities should act by harnessing these rapid and disruptive technologies of FIRe. Today's emerging cities become the center for innovation and economic activity that attract more number of people, and also provide transformational economic opportunities. It is also expected that these communities need to invest in the enabling technological infrastructure and skills to minimize negative impacts of FIRe. **Appendix A** illustrates the opportunities that these FIRe's disruptive technologies bring which have great influence for cities to harness innovation towards achieving SDG#11 (sustainable cities and communities).

4.3 Fourth Industrial Revolution and Higher Education

It is observed that the proliferation of new educational institutions and new curricula after the first two industrial revolutions enabled the technical and managerial capacity to implement the massive expansion of the economy and manufacturing (Penprase, 2018). Furthermore, the author explains that higher education system in some ways can be considered as an industry in itself— with billions of economic activity, thus this education industry itself is needs of an "industrial revolution." On the other hand, the 3rd Industrial Revolution moved toward online education which completely displace traditional in-person higher education and expand access to university education to millions of previously unserved students across the world. This online courses or commonly known as "long distance learning" enable students to more rapidly build skills and knowledge simultaneously. In addition, it also brought educators to free and easy access to information, a closer collaboration within diverse teams in a project-based and peer learning environment. Reforms in STEM (science, technology, engineering, and math) education in recent years have resulted in a greater emphasis on liberal arts and interpersonal skills within a more interdisciplinary curriculum (Penprase, 2018). Therefore, FIRe shapes the future of education, gender and work" and how the 4IR will require "accelerating workforce reskilling." (Garcia, 2018).

Kao (2018) as cited by Garcia (2018) observed that education and learning are diverging because of the utilization of technology. The authors adds that being a most disruptive factor, learning opportunities are becoming diverging but the accredited education programs are lagging behind. There is also skills gap between the present capabilities and the demand that FIRe created which affects the future roles of HEIs. Thus, to address these concerns, HEIs require multiple stakeholders – teachers, students, researchers, industries and the government and working together with common shared objectives (Ogan, 2018 as cited by Garcia, 2018) and mutual commitments to shape a shared future.

To effectively respond to the needs of the students in the 4th Industrial Revolution, higher education institutions (HEIs) are expected to adopt the concept of lifelong learning (Vestberg, 2018) which can be achieved through the following: (a) professional work integrates with educational process (b) internship and work experience (c) community immersion and (d) discipline-focused learning. Engineering and planning educators should challenge their students to become more resilient future professionals in a more engaging and enjoyable environments that motivate learning. Some of the strategies towards skill development of students are (a) leadership, (b) confidence (c) resilience, (d) self-efficacy. In this way, it allow students to be more competent, enterprising and innovative.

According to Van Dam (2017), the acceleration of technology shortens the shelf life of existing knowledge, expertise and skills, consequently require different competencies. By 2020, it expected top 10 skills are as follows: 1. Complex problem solving, 2. Critical thinking 3. Creativity 4. People management, 5. Coordinating with others, 6. Emotional intelligence, 7. Judgement and decision making, 8. Service orientation, 9. Negotiation 10. Cognitive flexibility. In addition, EU has developed a digital competence framework (**Appendix B**) – a tool to improve individual digital competence, help policy makers to formulate policies that support digital competence building, and to plan education and training initiatives to improve digital literacy. Having these wide range of deep knowledge and skills, HEIs play a major role to accelerate the learning and experience of the students to become abreast of becoming new breeds of workforce being driven by FIRE. On the other hand, Kamaruzaman et al (2019) came up with a conceptual framework as shown in **Figure 1** that illustrates the network and the relationship between the institutions, industries, students' and employers' requirements for graduate skills development.

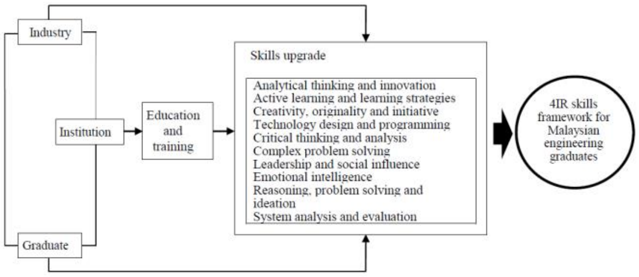

Figure 1. Conceptual Framework for FIRe's skills development (Kamaruzaman, 2019)

Similarly, WEF (2015) as cited by Dadios et al (2018), there are lists of 21st century skills that groups into: (1) foundational literacies, (2) competencies, and (3) character qualities as shown in **Figure 2**. It is recognized that foundational literacies are the basis on which students will build the competencies and character qualities. These competencies are needed to face complex challenges while the character qualities are what students need to navigate changing environments. The authors also emphasize that aside from generating competencies and skills, the quality assurance and certification systems should facilitate movement across formal, non-formal and informal education systems. The assessment and certification of knowledge learned outside the classroom are importance sources of building qualifications. Brown-Martin (2017) as cited by Dadios et al (2017), a key skill to be developed among learners is "learning how to learn" where the graduates embrace lifelong learning, continuous training and retraining.

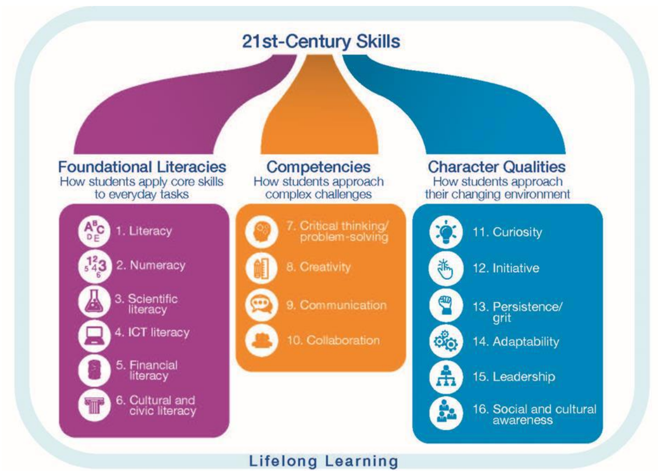

Figure 2. The 21st Century Skills (WEF, 2015)

Moreover, it is also expected that teachers should embrace technologies in both instruction and assessment towards continuous improvement in teaching and learning environments through lifelong learning and collaboration with other teachers (Brown-Martin (2018) as cited by Dadios et al, 2018). The government should also allocate adequate funds and other resources to train teachers in terms of developing syllabi and improving teaching methodologies and assessment to reflect 21st-century skills and expertise (UNDP, 2018).

In terms of academic curriculum development, it requires a substantial changes to the science and technology curriculum which allow students to develop capacity in these rapidly emerging technologies (Penprase, 2018). The author further emphasized that an interdisciplinary and global curriculum maximizes the development of intercultural and interpersonal skills, ethical reasoning, among students which will be a hallmark of the future FIRe workplace for graduates. Specifically, an academic curriculum should focuses on the interconnections between each scientific problem across global scales and interrelations between physical, chemical, biological and economic dimensions of a problem. Thus, HEIs should provide a future workforce not only capable of developing new applications and products, but also capable of interpreting the effects of these technologies on society and people on sustainable and ethical manner.

5 CONCLUSION

FIRe is expected to change the way we live and also transforms our communities we live in. This change/transformation brings challenges and opportunities that various stakeholders should embrace and prepare them acquire valuable skills through adequate trainings and lifelong learnings. To counteract this change associated by FIRe, it requires a proactive approach among these stakeholders to minimize the negative impacts of these disruptive technologies towards achieving SDGs by 2030.

Access to education services plays a vital part in ensuring that every individual has the required literacy, skills and competencies to respond to FIRe's challenges. In particular, higher education should provide engaging and motivating learning environment in order to produce graduates that are more resilient, competent, enterprising and innovative professionals. HEIs need to recognize of adapting and scaling up in the delivery of education services to assure the sustainability of the economy and the environment. Further, HEIs should be able to sustain its relevance being a responsive and vital component of society by offering curriculum that develop students both technical mastery and a deep awareness of ethical responsibility toward the human condition (Penprase, 2018); and also by allowing teachers/faculty to create a more targeted instruction (UNDP, 2018).

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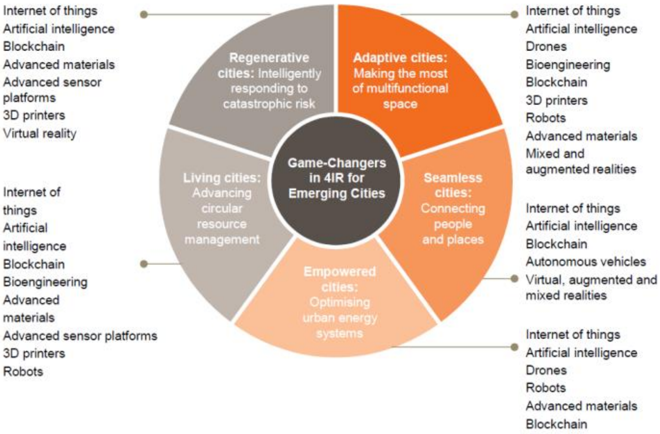
APPENDIX

Appendix A. FIRe's technologies for sustainable emerging cities



Appendix B. The Digital Competence Framework

Competence Areas	Competencies
Information	Browsing, searching and filtering information; evaluating information; storing and retrieving information
Communication	Interaction through technologies; sharing information and content; engaging in online citizenship; collaboration through digital channels; netiquette; managing digital identify
Content Creation	Developing content; integrating and re-elaborating; copyright and licenses; programming
Safety	Protecting devices; protecting data and digital identity; protecting health; and protecting the environment
Problem solving	Solving technical problems; expressing needs and identifying technological responses; innovating, creating and solving using digital tools; identifying digital competence gaps

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