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The Fourth Industrial Revolution and the Future of Engineering Education in South Africa

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Abstract: ***The process of change from a crude, agrarian economy to one dominated by industry and heavy machineries has taken a new facelift in the fourth industrial era. This era has in it a fusion of technologies in the physical, digital and biological sphere which can have profound impact on all industries and cause a shift in the models of business globally. There is a shift in the order of events and the fourth industrial revolution has with it velocity and exponential rate, breadth, and depth of convergence and its attendant import on industries, firms, government and the society at large. This research was framed as a qualitative study and a theoretical approach was used in providing support for the major thematic areas in this research article. A review of relevant pieces of literature in line with the topic under consideration was done to address the topic critically. This study reveals that there is a need for change along engineering lines since the traditional development models that have contributed to growth in the past might not be appropriate to maintain growth in the future. Exposing the need to have new techniques and business models that will influence present and future processes, this study recommends a rapid adaptation to global breakthroughs by South Africa, in order to ensure that all stakeholders vital to the educational, political and economic policies in South Africa, synergize to have in place factors that will ensure rapid uptake and local development of this emerging innovations.***

Keywords: Engineering, Engineering Education, The Fourth Industrial Revolution.

I. INTRODUCTION

Industrial revolutions are periods in modern human history where innovative technologies are applied to cause a rapid change in the socio-economic condition of people globally. There have been various stages in human history and the global economy has had three major industrial revolutions as humans began to increase in experience and knowledge of their environment coupled with the need for survival (Cunnighnam 2018). These industrial revolutions have expanded with development globally and it has with it opportunities and challenges. Klaus Schwab, the founder and executive chairman of World Economic Forum has opined that the fourth industrial revolution is unlike other revolution and with more velocity and exponential rate, breadth, and depth of convergence, it has attendant import on industries, firms, government and the society at large (Schwab, 2017).

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The essence is that there is a paradigm shift in what obtains in the past and this new reality has with it defining characteristics which will heavily impact all processes. With the fourth industrial revolution, there will be a change in the conduct of engineering education in South Africa.

Production has been a vehicle for growth, prosperity, and innovation and this can only be made possible through engineering education. However, according to WEF (2018A), it was argued that the traditional development models that have contributed to growth in the past might not be appropriate to maintain growth in the future hence, the need to have new techniques and business models that will influence processes generally. It is therefore important to examine avenues where the new developmental models will contribute to growth along engineering education line in South Africa. A report from a study conducted by the Royal Academy of engineering RAE found out that Africa as a region is constrained by a gap in engineering skills vital for the development of the region. With this deficiency in engineering skills also is the inadequate number of engineering graduates that are to contribute to the demands of the region. Though South Africa can be likened to be the center of engineering in Africa, there is still a shortage of engineering capacity in the nation. With the fourth industrial revolution, there will be massive breakout of technologies that will consequently influence and shape the practice of engineering education in South Africa. The fourth industrial revolution has various nomenclatures which include industry 4.0, smart industry, smart factory, smart manufacturing, etc., but for this study, the term fourth industrial revolution will be used.

According to Schwab (2017), "*the fourth industrial revolution is fundamentally different from the previous revolutions as it is characterized by a range of new technologies that are fusing the physical, digital and biological worlds, impacting all disciplines, economies, and industries"*.

With the series of changes that have occurred over time from the first industrial revolution to the fourth industrial revolution, the future will come with lots of challenges, opportunities and benefits for engineering education in South Africa. The changes that are happening recently are overwhelming and the speed and measure of the shift in paradigm that will come with the fourth industrial revolution cannot be trivialized.

To comprehensively address the topic under consideration, the research will shed light on challenges facing engineering education in South Africa, holistically analyze the fourth industrial revolution and consider the future of engineering education in the era of the fourth industrial revolution.

II. METHODOLOGY

This study is an analysis of the fourth industrial revolution and the future of engineering education in South Africa. With the novelty of the topic, evidences from literature published between 2013-2019 such as policy documents, government strategies, international organization reports, government report, and consultant's reports were used as primary sources of data. These documents contain valuable information on government investment and efforts, economic challenges etc. collecting these information using interviews and questionnaires would be challenging as a result of time and economy so valuable insight from the documents were analyzed using document analysis and various themes emerged from the process.

1. The Fourth Industrial Revolution: Emerging Challenges

With the massive opportunities the fourth industrial revolution **has** on engineering education, so also are challenges associated with it. Apart from the challenges it inherently has, the pace and scale with which this revolution is emerging cannot be compared with previous revolutions hence, the challenges that will come with it. With massive technologies characterizing the fourth industrial revolution, it could come with the following challenges.

According to the World Economic Forum (2016), the major avenues of transformation in the globe has been predicted to influence the pattern of work which ranges from job creation, job displacement, skills gap, increased labour productivity. This argument revealed that as a result of the technologies embedded in the fourth industrial revolution, there will be a shift in the job pattern and this can result to job losses for citizens. Automation by the use of technologies reduces the human factor to production and with these technologies, most human routine and repetitive task can be carried out conveniently with the use of robotics. The only feel of humanity to it will be for control and administrative processes which a high percentage of people cannot be involved in. with high index of unemployment of about 26% in South Africa (Statistics South Africa, 2018) this change will increase the challenges associated with the country.

With the rapid pace at which these technologies in the fourth industrial revolution are developed, there will be also be challenges associated with skills. To leverage on the fourth industrial revolution, skills, innovation and knowledge are pivotal in the implementation of technological initiatives (Scholl & Scholl, 2014). To have a successful smart society where technologies will be leveraged on, skills are important (Manda & Blackhouse, 2016b). With these new technologies, there will be need for a skills upgrade among the entire workforce in South Africa so as to overcome the challenges of skills mismatch, skillset redundancy as a result of job changes (World Economic Forum, 2016). There must also be access to the internet to be able to tap into these technologies. This is called e-readiness and low e-readiness in South Africa has been argued to be a hindrance to the success of smart cities (Manda & Blackhouse, 2016b).

What characterizes developing countries is massive infrastructural deficit which has affected the pace of development in the region. The poor nature of infrastructure which ranges from electricity, information communication and technology will considerable affect the introduction of new technologies. Broadband penetration is still not adequate in developing countries like South Africa (United Nations, 2014: International Telecommunication Union, 2015). Poor broadband penetration has been revealed to be a major challenge to the development of smart cities in South Africa (Manda & Blackhouse, 2016b).

Availability of access to large volumes of data from various sources in the fourth industrial revolution will result in security and privacy issues (Waidner & Kasper, 2016). Therefore, the application of these systems in the fourth industrial revolution must consider the creation of new security mechanism, to curb issues of privacy and data breach. With the large volume of data, data analytics will take a new shape and new challenges will emerge from it which ranges from trust issues in the new smart era.

Also, the challenges associated with the fourth industrial revolution will include issues of ethical consideration in production and work processes. Arguments will ensue on what is right in the light of new development and what might be wrong on the grounds of ethics. There will also be disproportionate inequalities among countries of the world.

2. Analysis of the Fourth Industrial Revolution

The technologies that were seen in the 19th and 20th centuries are gradually becoming irrelevant in the 21st century and there has been the pervasive breakout of technology to address the current challenges faced in the world. From the first industrial revolution which had in it mechanization that steadily replaced crude agriculture to the second industrial revolution which saw the emergence of various sources of energy, electricity, oil and gas and the development of the combustion engine, chemical synthesis and communication methods to the third industrial revolution where a new source of energy with more potency (nuclear energy) came to the fore to the fourth industrial revolution rapidly unveiling before our eyes with digitization at its core. This is supported by the findings of Schwab, (2016) who opined that the first industrial revolution was driven by steam and water energy, the second industrial revolution by electricity and the third industrial revolution by information and communication technologies. The fourth industrial revolution is characterized by a proliferation of various technological innovations and according to Schwab (2016), the fourth industrial revolution is driven by technologies such as automation, additive manufacturing, and the industrial internet. This paradigm is changing the conduct of activities and processes and there is a lot to benefit from it in this current clime. This can be attested to by the need to have seamless processes where automation will be the major order, the need to leverage on data to make the best out of all activities, the overall change in industrial processes, etc.

What lends credence to the breakout of new technologies was attributed to a merger of various technologies across the physical, digital and biological worlds and these processes are resulting in significant changes across board with the emergence of new business processes that influences everyday interaction in the society (Schwab, 2017). With the interconnectedness of the physical, digital and biological worlds, various emerging technologies is capable of influencing daily human interaction and industrial processes. The fourth industrial revolution will come with changes in the labour market,

as it will seek to replace lower-skilled workers with competent highly skilled workers. The imperative of skills will be felt more in this era and to ensure relevance, there must be capacity building to skill up to meet these realities (Autor and Dorn, 2013).

Some of the new skills pivotal to this changing paradigm are social and creative intelligence, leadership and top management skills, skills in art and entertainment. With automation becoming a major agenda in this era, there will be a need for a more human approach to processes hence the need for social and creative intelligence which resonates with emotions. Also, leadership and management will be reinforced in this era to conduct highly technological industrial processes. Africa lagging in the necessary skills for production, and many low skilled jobs along industrial lines might be replaced by automation. This is in line with the findings of Frey et al (2016) who argued that 66 percent of all jobs in the developing countries might be predisposed to risks. This implies that these jobs with time will be made subject to automation and if people do not improve on their skills bank, they might not be relevant in the scheme of events.

The emergence of the fourth industrial revolution presents adverse consequences for developing countries such as South Africa. Developed countries outsource their manufacturing and industrial processes to low labour cost workers from developing countries. This is billed to change when automation eventually becomes the order of the day. The use of human labour in industrial processes will drastically reduce, throwing a lot of people out of their jobs.

This opinion typifies that the need for labour will be replaced by automation in the fourth industrial era. The push by developing countries to move their labour to factory jobs will be affected (Frey et al, 2016). It is therefore imperative for South Africa to rapidly embrace processes that will ensure that the labour force is skilled up for the imminent changes. The future will come with job losses for South African graduates who are not equipped with the required knowledge to compete in the ever changing innovative globe (Marsh, 2014).

3. The future of engineering education in the era of the fourth industrial revolution

Production generally in the globe has been a major driver of the economy and it is a key part that ensures innovation and economic prosperity. This product cannot be made possible without the apparatus of engineering education hence the importance of engineering education in production. The evolutionary spread of industrialization from the first industrial revolution to the ones in the past might not be viable in the future as revealed by the WEF (2018A). Hence, the fourth industrial revolution has come with lots of opportunities to shape the future of engineering education and this will be made possible using automation, additive manufacturing, and industrial internet.

The fourth industrial revolution in engineering education will close the chasm between inventors and markets as a result of new technologies such as 3D printing. Taking, for instance, tissue engineers can apply this prototyping technique to create 3D porous scaffolds that will be used for their operation. The future of engineering education will be shaped largely by the close synergy between inventors and the market. There will also be a wide breakout of new entrepreneurs along engineering lines that will leverage the new technologies such as 3D printing to establish small startups. With ideas coming to entrepreneurs, the entrepreneur can conceptualize and bring the idea to reality using 3D printing and this is done without jeopardizing time. The fourth industrial revolution will influence engineering education in the future and it will cause significant disruptions in economic growth. According to Manyika *et al* (2017), a report by Mckinsey & company revealed that half of all existing work activities would become automated using the current technologies that come with the fourth industrial revolution. For instance, autonomous trucks in engineering may influence shipping and there will be lesser jobs for truck drivers and also driverless cars will replace taxi and Uber drivers.

With the need to work in a dangerous environment in engineering education, the fourth industrial revolution offers more opportunities with robotics. Having a machine interface to conduct activities along engineering lines has benefits in areas considered dangerous for humans such as fire scenes, confined environment, dangerous chemical infiltrated environment, etc.

The future of engineering as a result of the fourth industrial revolution will have fewer jobs. Taking a cue from events happening before, it was revealed that engineering education is y constrained by gross undersupply of engineers and those that are available do not have the necessary qualifications and skills that are germane to the practice of their profession. Hence their poor engagements in the discipline of engineering education as their skills do not meet up. This dismal reality is the fact that the available jobs will require advanced skills (WEF, 2017) which will be in the form of innovative, social and creative skills that are pivotal to the realities of the 21st century. With the problem of undersupply of engineers, poor skills and qualifications in developing countries, the advent of the fourth industrial revolution will come with lots of challenges such as job losses for those already deficient in the vital skills needed in this era. With technologies such as artificial intelligence and automation, this might disrupt many jobs along engineering and production lines. Hence, the consequential disregard for those without advanced skills to meet up with the changing world. The onus is on the government to train and retrain the current employees to fill the skills gap created by the job changes the fourth industrial revolution will bring (Schulz *et al*, 2018).

According to the World Economic Forum(WEF), the fourth industrial revolution will cause a change and bring about development in business processes which will change the whole production process, government decision, industry and society at large. With a whole new approach to the practice of engineering education in the fourth industrial revolution era, production and industrial processes will change and the future of engineering education will come with new sets of challenges and uncertainties that must be solved. Some of the new challenges this change in the fourth industrial revolution will bring include human-machine interaction, cyber security, privacy, and data security which if not taken care of, can have grievous consequences for national economies.

In engineering education, the future will be influenced as argued by WEF and firms such as AT Kearney.

One will be a change in mass manufacturing to increased efficiency, flexibility and cost-effectiveness of mass customization. With production having a turnaround, the fourth industrial revolution promises a more efficient, flexible and cost-effective approach to engineering education and this can be made possible by rapid advancement in additive manufacturing (3D printing), new materials development and smarter customization techniques.

With the fourth industrial revolution as revealed by WEF, there will be mass personalization in engineering which will be made possible by social technologies, data processing capabilities, a better synergy of customer choices into purchasing, production, and logistics. There will also be the need to complement human effort in engineering education by having artificial intelligence to support most engineering practices which can be made possible by having access to large volumes of data and the ability to manage and process the data and the application of advanced technologies to kick start it.

Engineering education will be influenced in the era of the fourth industrial revolution especially along industrial lines. The last decade has witnessed lots of changes that influenced industrial processes and this new age offers more that will alter engineering processes. In engineering education, the future will be changed arising from three major technological processes which are automation, additive manufacturing, and industrial internet. These all will be discussed to support the crux of this research work.

With an estimated 170 million workers in Africa's workforce by 2010 and 2020 (fox et al, 2013) there will be a need for more jobs. In Africa, agriculture employs a large percentage of the population and it also contributes to the Gross Domestic Product. The nature of agriculture carried out is crude, conservative and it operates on smallholdings which might not be able to provide the needed potential to absorb more workers in the coming years. Hence, the scourge of unemployment increases in Africa. With mining being a sub-discipline under engineering education, it has been one of the most productive sectors in Africa and it relies on technologies that might be capital intensive. The fourth industrial revolution offers immense benefits to engineering education thus shaping and influencing it by pursuing industrialization in the fourth industrial revolution in Africa, there will be hopes of new jobs which will ensure more productivity.

There is a vital need for industrialization in Africa which can only be done through engineering education. Though there are significant changes in what obtains in the past and now, there is a need for relevance in the 21st century and to achieve this, there must be nothing less than the embrace of the fourth industrial revolution and the importance will influence engineering education along three lines which are automation, additive manufacturing and industrial internet. With engineering education is a complex process that has in it varieties of duties and functions, having an automatic approach to some will confer more benefits on the discharge of the discipline and with additive manufacturing, business models will change bringing new inventors and markets to the fore while industrial internet will offer more benefits on engineering education leveraging on a plethora of data that can influence the discipline. While there are many opportunities and benefits for engineering education as a discipline in the fourth industrial era, there are also threats associated with it. With the emergence of these innovations in the fourth industrial revolution, there will be issues associated with ethics, security, rights, and privacy. Success largely along these lines will be predicated on how well each country in Africa adopts and grab the opportunities the fourth industrial revolution has in it and use it to face the current challenges in the region.

III. FINDINGS AND DISCUSSION

Findings from the study revealed that with South Africa being home for engineering education in Africa, the country has a comparative advantage of being equal with other countries of repute. With the advances in technologies, there will be an immense contribution to the betterment of the welfare of the people compared to the previous revolution. These advances in technologies in the era of the fourth industrial revolution will also come with some challenges such as job disruption World Economic Forum (2016), privacy and security issues (Waidner & Kasper, 2016), ethical interests, inequalities, etc. There is, therefore, a need for socio-political structures that will facilitate the easy absorption of these technological innovations.

With the various evolution from the simple mechanism of production in the first industrial revolution, to mass production in the second industrial revolution to the major automation in the third powered by advances in information and communication technologies. The world is now at a new stage called the fourth industrial revolution and the intensity, speed, velocity associated with this stage are different from what obtains in previous stages of development. The world at this time is rapidly changing and there is a need for South Africa to adapt rapidly to these changes or risk the possibility of stagnancy or not meeting up with another comity of nations. With the immense benefits the fourth industrial revolution has on the practice of engineering education, these technologies can ensure that South Africa rises to an enviable status with other developed economies if properly adhered to.

The fourth industrial revolution has come with lots of opportunities to shape the future of engineering education and this will be made possible using automation, additive manufacturing, and industrial internet which were expatiated on above.

IV. CONCLUSION AND RECOMMENDATION

This research has examined engineering education in South Africa in the era of the fourth industrial revolution and it has considered the challenges of engineering education, the opportunities the fourth industrial revolution has on the practice of engineering education. In this era of fourth industrial revolution, the speed, complexity, and pace at which it will be adopted by various countries especially in developing nations will not be the same and this might be attributed to the economy, proximity to westernization, level of exposure, educational level, etc. with South Africa being the centerpiece of technology in Africa, effort has been made by various stakeholders to key into the various technologies emerging from the fourth industrial revolution. This will, in the long run, have major contributions to social and economic development in South Africa.

For a transformation in South Africa, there is a need to encourage engineering education and this would require policies that will encourage the adoption of the fourth industrial revolution and the technologies emerging from it. This necessitates policies that will influence engineering education practitioners to adopt automation, additive manufacturing, and industrial internet. It is also important to build the knowledge bank in Africa and this can be done by the government making policies that will address issues of deficit in the educational sector. When this is done, graduates will be saddled with the necessary skills and qualifications that will make them relevant in the fourth industrial era and as the future is changing, there is a need for constant change too by engineering education practitioners to align with these changes. It is therefore important to ensure that all stakeholders vital to the educational, political and economic policies in South Africa synergize to have in place factors that will ensure rapid uptake and local development of these emerging innovations.

Further research and analysis is needed on the state of adoption of these technologies in South Africa and how they can be made relevant to the culture of the country. With westernization being a major challenge of engineering education in South Africa, there must be effort geared towards developing technologies that upholds values and culture resident in the country. When technologies are westernized, they might not really be adaptable to the local conditions prevalent in an area. so the need to have relevance along technological lines in South Africa. There is also need for further research on gender dimensions to these emerging technologies. With engineering education in South Africa being biased along gender lines, effort must be made to have gender friendly technologies in engineering education that will close the gap between gender lines in the discipline. With this in mind, sustainability will be guaranteed as all sexes pivotal for development will be involved. These are all salient points that must be addressed in the future of engineering education in the fourth industrial revolution.

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