

The language of Engineering Education in the era of the Fourth Industrial Revolution

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Abstract: *Engineering was defined by the Royal Academy of engineering as the creative use of scientific principles to invent, design, build, maintain and improve structures, machines, devices, systems materials and processes. From the creation of simple tools to the complex engineering machineries which abounds now, the journey has been chronicled into series of epoch Industrial revolutions are periods in modern human history where innovative technologies are used in ensuring rapid change in the socio-economic condition of people globally. The fourth industrial revolution is an era of massive technological breakthrough. The era is driven by technologies such as automation and robotics, additive manufacturing and the industrial internet. This study conceptualized the language of engineering education in the era of the fourth industrial revolution as the means through which the knowledge of engineering education is communicated. Findings from the study revealed that the industrial revolution is responsible for some changes in engineering education and it has with it immense opportunities for the conduct of the discipline. Some of the opportunities of the fourth industrial revolution on engineering education is the overhauling of production processes, the possibility of remote monitoring of engineering projects will also be made possible as a result of the technologies brought about by the fourth industrial revolution. The study therefore recommends that that efforts be intensified on developing the languages in which engineering education is communicated in the fourth industrial revolution.*

Keywords: *engineering, engineering education, fourth industrial revolution*

I. INTRODUCTION

Engineering is defined by the Royal Academy of engineering as the creative use of scientific principles to invent, design, build, maintain and improve structures, machines, devices, systems materials and processes. This definition typifies the dynamic nature of engineering and its propensity to proffer solution to many challenges. With the need for human evolution and survival, various evidences from human history has attested to the impetus of engineering education as a viable tool for development. From the creation of simple tools to the complex engineering machineries which abounds now, the journey has been chronicled into series of epoch tagged the industrial revolutions and according to Shawn Cunningham (2018) industrial revolutions are periods in modern human history where innovative technologies are used in ensuring rapid change in the socio-economic condition of people globally. We are at the fourth industrial revolution now and there is the emergence of various technologies. The fourth industrial revolution is an era of massive technological breakthrough (Schwab, 2016).

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The era is driven by technologies such as automation and robotics, additive manufacturing and the industrial internet. From historical perspective, the first industrial revolution was powered by steam and water energy and this kick started the series of events tagged the industrial revolution. The second industrial revolution was driven by electricity while the third industrial revolution was driven by information and communication technologies (ICT) (Schwab, 2016). The fourth industrial revolution is characterized by a merger of various technologies along the physical, digital and biological worlds which has caused tremendous shift and transformation across disciplines, industries and society. with the dawn of the fourth industrial revolution, the language of engineering education is assuming a change as the revolution has made tremendous impact on the conduct of the discipline.

This study will therefore conceptualize the language of engineering education in the era of the fourth industrial revolution as the means through which the knowledge of engineering education is communicated. The study will also seek to analyze the fourth industrial revolution and the change in engineering education and also consider the opportunities for engineering education in the fourth industrial revolution.

II. METHODOLOGY

This study aimed at understanding the language of engineering education in the fourth industrial revolution. The language of engineering education was conceptualized as the means by which engineering education is communicated in the fourth industrial revolution. To achieve this, evidences from literature were reviewed from which findings and conclusions was reached. Studies that have been empirically done that are related to this studies were reviewed and their findings were used as conclusions for this study

Understanding the industrial revolution and the change in engineering education

According to the Cambridge dictionary (2017) industrial revolutions are periods of time in which the nature of work done by hand is replaced more by machines. This typifies that there has been a certain level of development in expertise and knowledge which has culminated in various ways of easing production process. As man continued to evolve, he has gained more mastery of the environment and all that surrounds him and he interacts constantly with the environment for survival. From building of simple tools to till the ground, make fire to generate heat etc., man has evolved to develop into a being capable of creating machines that will ease his production.



The language of Engineering Education in the era of the Fourth Industrial Revolution

The time line between each epoch of mastery brought about by widened knowledge base and civilization has been tagged industrial revolution. Taking a reference from history, the stages have moved from the first industrial revolution to the fourth industrial revolution. The rate and pace at which these revolutions take place is different as a result of certain prevailing conditions. Also, S Cunningham (2018) defined industrial revolution as periods in modern human history where innovative technologies are used in causing a change and transformation in the socio-economic conditions of people globally.

Although there is no general consensus on what wholly constitutes that industrial revolution (Maynard, 2015), four general phases have been identified (National Academy of Science and Engineering, 2013). The first industrial revolution is the starting point for the industrial revolutions and it is seen as one of the most important advancement made in humanity. The first industrial revolution was powered by water and steam-driven mechanical manufacturing devices since the end of the 18th century. This helped in expanding production and manufacturing processes then as the mercantile economy came to the fore. Commerce was boosted and heightened as people traded more in some of the goods manufactured as a result of the impetus of the first industrial revolution. Briefly after the start of the 20th century, electricity powered technologies came to the fore and this gave more credence to production and division of labour which was tagged the second industrial revolution. Around mid-1970s, the third industrial began which had a boost on automation of manufacturing and electronics and information technology was popularized.

According to Klaus Schwab (2016) chairman World Economic Forum, he opined that the fourth industrial revolution is a stage that builds on the third industrial revolution. The fourth industrial revolution according to him is a fusion of technologies that blurs the divide between the physical, digital and biological spheres whose velocity, scope and impact is on a massive scale. The rate and pace at which the fourth industrial revolution is evolving is fast compared to subsequent revolutions and it has disruptive effect on every facet of the economy. The fourth industrial revolution according to Klaus (2016) has in it artificial intelligence, driverless and autonomous vehicles, unmanned aerial vehicles or drones for virtual assistance, robotics, cloud computing, digital fabrication, additive manufacturing, materials engineering etc. the breakout of these technologies has the potential to affect production capacity and patterns and it also has with it certain consequences. It is important to bear in mind that with these technologies made possible by engineering education, the language of the discipline is undergoing a change and with more application of the fourth industrial revolution in engineering education, the conduct and pattern of the discipline will witness tremendous overhaul.

According to the World Economic Forum (2016), the fourth industrial revolution is characterized by widespread development in the field of artificial intelligence, machine learning, robotics, nanotechnology, 3-D printing, genetics and biotechnology which have influenced and cause massive disruption in the conduct of

business leading to new business models and labour market. With the poor investment in education and training systems, it has resulted to production of skills that are inadequate for the new labour market (World Economic Forum, 2017) and there is a need for higher education institutions (HEIs) globally to have a review of their curriculum so as to be in line with the skills and competencies that are vital in the fourth industrial revolution. These will in the long run improve employability and entrepreneurial drive in the graduates in the era of the fourth industrial revolution.

The fourth industrial revolution has also been described as an upheaval that is impacting different sectors of the society (Schwab, 2019). From history, various happenings in time past have caused a change in the conduct of events globally and these happenings are defining moment for change to occur. Take for instance the invention of the movable types by Guttenberg in 1441 caused a paradigm shift in the art of prints which led to more impetus for the art of reading and writing. Also the discovery of the polarity of the magnet brought about certain changes in movement along cardinal poles which was applied in producing the mariners compass, the discovery of gun power by Roger Bacon also shaped the art of war while the discovery of penicillin caused a change in medicine. These all are profound discoveries made in history which caused disruption and had ripple effect on the conduct of events globally. So also, the fourth industrial revolution is an agent of disturbance to the current mode and model of production and economic market. What will differentiate each nation from the other is the level of investment made into education to leverage on the opportunities that come with the fourth industrial revolution.

Production has been pivotal for growth, production, prosperity and innovation and it is done using the apparatus of engineering education. This typifies the importance of engineering education as a vital tool for production processes. The traditional models of production that has contributed to growth prosperity and innovation in the past might not be apt to encourage growth and prosperity in the future and hence, the need to have new technologies and business models that will cause massive influence on the production processes generally in all clime. With many benefits from the fourth industrial revolution comes great disadvantages too. It was opined that the fourth industrial revolution is not an exception to the previous industrial revolutions but it has with it the ability to cause immense change and benefit and challenges. Some of the challenges that concerns stakeholders is the cyber security risk which is associated with the internet of things (IoT) being the backbone of the fourth industrial revolution. The internet of things (IoT) has the potency to enlarge the risk that comes with using internet connected devices exponentially more than ever before and this must be considered in all policy analysis that concerns the fourth industrial revolution. The pace at which the fourth industrial revolution is taking place is also massive which makes it challenging to have full grasp of all its dimensions and the challenges that might come with it.



This difficulty has been attributed to the massive, pervasive and high convergence of technologies that could complement or compete with different existing scenarios and cause further technological breakthroughs that might not be easy to predict.

Other social challenges might emerge such as the risks that comes from cybercrime due to widespread connectivity and job losses as a result of automation of a large segment of the industries. Though, different skill sets are needed in the fourth industrial revolution which might not be seen in people now. This predisposes them to job losses and to avert this, more impetus should be placed on investment in education and training which can guarantee that people have the right skills to thrive in the fourth industrial era. According to Drucker (2014), there might be new opportunities for people with high-skills which might not be enough to meet the supply of labour in this time. These consideration has raised intense discussion about some of the technologies in the fourth industrial revolution and most of the discourses are about the uncertainty that come with the best way of exploring these technological innovations to improve human life and industrial processes (Friess & Ibanez, 2014; Vermesan et al.,2014)

Opportunities for engineering education in the fourth industrial revolution

Production has been reputed as a major element for growth, prosperity and innovation and it has been observed that there are differences in the economies of the world which is manifested in accelerated growth and development brought about by industrialization. Takin evidences from history, the first industrial revolution which was powered by invention of steam engine which led to transition from manual labour machine resulted in emergence of work specialization, establishment of professional schools, development of universities. This generally influenced production processes and the elements of industrialization was given more impetus. An evolution from the traditional industrial development models that were apt and applicable in previous epoch might not be viable now and in the future as revealed by World Economic Forum (2018a). This has been a major driver for industrialization as developing countries are on a quest to not fall to a decline and developed countries are also on a quest to keep up as falling behind could have grievous economic and social consequences.

With various technologies breaking forth from the fourth industrial revolution, there will be lesser divide between production and market. With widespread application of 3-D printing, robotics and automation, artificial intelligence, Nano technology, material science etc. This has been revealed to cause a shift in production processes and patterns and this will result in the development and implementation of future industrial procedures. Take for instance new technologies like the 3-D printing, can be applied in producing engineering devices such as porous scaffold. This has the potency of closing the nexus between inventors and the market. With the new technologies, there will also be breakout of new crop of investors along engineering lines that will leverage on the technologies that come with the fourth Industrial revolution.

General production processes will be overhauled as a result of the fourth industrial revolution. As revealed by Manyika et al (2017) in a report by Mckinsey & company, it was revealed that half of all the existing work process will become automated as a result of the technologies that come with the fourth industrial revolution. with driverless autonomous vehicle, movement of engineering materials will be changed, robotics and automation will encourage faster work process, reduce monotonous work and fatigue, encourage work in dangerous and confined zones, radioactive sites etc.

The possibility of remote monitoring of engineering projects will also be made possible as a result of the technologies brought about by the fourth industrial revolution. take for instance, a situation where a project manager might be constrained by distance in an ongoing engineering project, incorporating elements of the fourth industrial revolution will ensure that such barrier in space and time is removed. With virtual conferencing rapidly becoming a norm, remote monitoring can be done right from mobile devices and the project can be monitored in quick time with update from other engineers. With wide advances in communication and information processing function, there is widespread connectivity, synergy and integration between platforms and automation. Entities existing individually in time past are now becoming interconnected which will definitely influence the world of work in engineering education.

With the fourth industrial revolution having profound benefits on engineering education, it also has with it certain consequences on jobs and employment. It was observed by WEF (2017) that there are few jobs created by new industries and those jobs require advanced skills. It is noteworthy to bear in mind that the skills, capabilities and competencies that were pivotal for employment and engagement in time past has experienced an overhaul and the skills needed in the fourth industrial era are different. Technologies that also have the capacity to remove the human barrier in production processes such as artificial intelligence and robotics will disrupt many jobs in the labor-intensive industries which engineering education is a part of. This implies that engineering education in the fourth industrial revolution will be affected in terms of jobs and employment and the onus is on people to build capacity to acquire advanced skills which will make them relevant in this era. The skills of the fourth industrial era include critical and analytical thinking, creativity, emotional intelligence, communication, leadership etc. These are vital to people's relevance career wise in the fourth industrial revolution. it is also important to note that such massive breakout of technologies cannot completely override the human dimension to context. The humanity dimension is still very important and all the elements of the fourth industrial revolution are still subject to human machination. Positioning one self and acquiring the right skills to become relevant in the fourth industrial revolution is important.

The language of Engineering Education in the era of the Fourth Industrial Revolution

The fourth industrial revolution came with a pace and velocity that was unlike other revolutions and understanding all the challenges that might come with might be herculean. This was revealed by Schwab (2017) who maintained that the fourth industrial revolution is different from other revolution because of its velocity and exponential rate, breadth and depth of convergence, effect on industries, firms, government and the society at large. The pervasive outbreak of these technologies has come with a force unequalled and understanding the various dimensions of it will only be made possible as time passes. There is therefore the need for awareness on the anticipated and expected changes that might occur as the fourth industrial revolution expands and gains traction.

Conceptualizing the language of engineering education in the fourth industrial revolution

Millardet (2004) opined that engineering education rests on a three legged structure which are science, mathematics and *techné*. This suggests that engineering education as a discipline is championed by the three factors stated above. The means through which engineering education is communicated will be conceptualized using Millardet (2004) three legged structure which are science, mathematics and *techné*. These all have been pivotal in ensuring communication of engineering education. It is important to bear in mind that without these three factors, engineering education will have no substance and its essence will be lost. Having these factors will contribute more to what the discipline entails and help in realizing its ideals. The language of engineering education in the fourth industrial revolution helps in understanding and grants access to concepts and instruction in the discipline. The means by which we explain, justify and otherwise communicate engineering education is important to the overall development of engineering education in the fourth industrial revolution. Mathematics has been a major part of human life and mathematics as a discipline according to Dunnett (1994) is the use of shape, quantity and arrangement in forming new patterns that showcases the truth or falsity in such patterns by mathematical proofs. There is a need to deploy mathematics in understanding various problems because it has with it the power to reveal what obtains or what does not obtain in any situation. With the fourth industrial revolution, there is a new level of intelligence which people must adhere to thrive. These are the skills relevant in the fourth industrial revolution. Some of these skills are creativity, analytical thinking to solve problems and they have ties with mathematics. This is in line with the findings of Liaqat (2015) who maintained that mathematics is not only important in solving everyday problem but it also include the application of imagination, intuition and reasoning to solve complex problems. With the fourth industrial revolution being a fusion of physical, biological and digital technologies, there is the emergence of various automated production technology with massive historical data. There is a dire need to define the data and make decision daily. This necessitates the need for mathematical knowledge and analysis. This is done by transforming data into decision making that returns profit.

With the emergence of deep learning technologies, it triggered artificial intelligence (AI) in the fourth industrial

and deep learning technology as a new algorithm has mathematics at its core. It is important to say that knowledge in the field of mathematics is a veritable language in which engineering education is communicated in the fourth industrial revolution. Mathematics is essential for digital technologies and there is a need to develop mathematical ability in people to leverage on the immense benefits it possesses. Also, mathematics is the basis of many sciences and it gives credence to development in other fields. Mathematics as a language in engineering education helps in achieving innovation in the fourth industrial revolution. Peregrina Quintela, president of the Spanish network mathematics industry (math-in) and director of the technological institute of industrial mathematics maintained that mathematics has always gone hand in hand with scientific and technological advances. This implies that without mathematics, the benefits that come with the fourth industrial revolution cannot be fully harnessed hence, it is an important language.

Mathematics is the language applicable in understanding and delivering scientific solution to the problem at hand. To delineate between physical problems, there must be the specification of certain parameters in a bid to understand the problems and this can be made possible only by the language of mathematics. Each mathematical expression represents equivalent physical problems and the application of a mathematical model or statement would ensure more understanding of the problems. This interconnection and fusion of mathematics and engineering education is becoming very valuable at the fourth industrial era as a result of the fusion of physical biological and cyber physical technology as captured in the words of Schwab (2016). In the fourth industrial revolution, there is a nexus of connection with other disciplines which can only be made possible by the language of mathematics. Depth in mathematics provides a basis for strong engineering problem solving foundation Mathematics has been reputed to go hand in hand with scientific and technological advancement. Mathematics is an important domain in engineering and other scientific disciplines in the fourth industrial revolution. The importance of mathematics in engineering education cannot be trivialized as the interpretation and solution to certain problems require the direct application of mathematics. This implies that some problems cannot be properly understood without proper knowledge of mathematics. To do this, elements of mathematics such as statistics, linear algebra, differential and integral calculus are applicable. Mathematics is a language of engineering education in the fourth industrial revolution as it has tremendous influence on it. Engineering education cannot be made possible without mathematics as a language. A statement by Reyes Maroto, minister of industry, trade and tourism stated that in the era of the fourth industrial revolution, mathematics is the basis of all emerging technologies which include artificial intelligence, 3D printing, block chain technology, internet of things (IoT), machine learning, robotics and automation, etc.



Techne as a major part of the factors enhances creativity which separates an engineer from a scientist. Engineering education is a creative discipline which follows some steps in conceiving, creating, design and effect. Most of the massive innovation seen in the global front can be attributed to the work of trained persons in the field of engineering education. As contained in the works of Olav Eikeland (2014), *techne* was seen as an art which was likened to latin “ars” and English “art”. It has with it double meaning and it indicates what an artist does and what a technician does. This is manifested with a certain level of expression and creativity which is not delineated with clear rules beyond which self cannot be expressed. This implies that *techne* has with it a certain degree of liberality and freedom in being expressed. The mind is discretionary and it is filled with unexplored realms of untapped skills which can only be reinforced until it is harnessed. This is what *techne* does. It brings to the fore the skills and dexterity to proffer solution to challenges. The double meaning *techne* has is delineated along the creative and expressive art and the mechanical pole.

Creativity is important as a language in the fourth industrial revolution and it has been listed by the World Economic Forum as the third necessary skill vital for survival in the fourth industrial revolution. Creativity also encourages innovation and innovation is important in the fourth industrial era. Thus in engineering education in the era of the fourth industrial revolution, *techne* has been a major language by which the discipline is communicated. Taking evidences from various perspectives on *techne* highlighted above, the need for a form of art that is creative cannot be trivialized. This is demonstrated in some of the skills that are relevant in the fourth industrial revolution which has creativity as a major part. Creativity in the fourth industrial revolution has its root from *techne* which has always driven the consciences to create using mindful discretion in an applied manner. Proficiency in engineering education depends on a continuous growth and blend of various techniques and critical skills such as concepts, procedures, algorithms etc.

Science is another language that drives engineering education. Science is the systematic study of the nature and behavior of the material and physical world which is predicated on observation, experiment, measurement and the creation of laws to describe facts (science, 2012). Science improves the human understanding of the physical world while developing research, experimentation and collaborative skills (Siekman G, Korbel P, 2016). Science is based on observation, experiment, measurement and laws and its values include independence of thought, creativity, tentativeness, subjectivity, testability and cultural and social embeddedness (Akerson VL, Burgess A, Gerber A, Guo M, 2018). The import of sciences as a vital tool for engineering in the 21st century can be confirmed in President Obama's acknowledgment address at the National Academy of Sciences when he stated that

“At such a difficult moment, there are those who say we cannot afford to invest in science, that support for research is somehow a luxury at moments defined by

necessities. I fundamentally disagree. Science is more essential for our prosperity, our security, our health, our environment, and our quality of life than it has ever been before.”

The importance of science in modern societies has been acknowledged in the works of Xie & Killewald (2012). It has been reputed to promote technological innovation and economic sustainability in nations. Science is vital as a major language in the fourth industrial revolution and Scientific knowledge is creating opportunities and solutions, while at the same time fueling disruptive waves of change in every sector.

III. FINDINGS AND DISCUSSION

Four general phases have been identified (National Academy of Science and Engineering, 2013) in the industrial revolution. The first industrial revolution is the starting point for the industrial revolutions and it is seen as one of the most important advancement made in humanity. We are at the fourth industrial revolution which has immense benefits to humanity and systems. At the fourth industrial revolution, there is a fusion of technologies across the biological, digital and cyber physical systems which occur with wide velocity. Findings from the study revealed that the language of engineering education in the fourth industrial revolution does not necessarily mean the spoken word or diction but the means through which essence is given to learn more about engineering education in the fourth industrial revolution. Findings from this study revealed that though there are no general convention on languages by which engineering education is communicated in the era of fourth industrial revolution, they can be conceptualized using evidences. The languages were seen as those elements that have facilitated the knowledge and development of engineering education in the fourth industrial revolution. The work in engineering education is predicated on science, mathematics and *techne* and by the knowledge of it, engineering education is communicated. With the need to turn abstract situation into meaningful scenarios, knowledge of mathematics is important and It was revealed in the study that mathematics is the foundation of all other sciences. *Techne* manifested in creativity was found to be pivotal for innovation in the fourth industrial revolution and according to Klaus Schwab, it is one of the most important in the fourth industrial revolution. Science as a language improves the human understanding of the physical world while developing research, experimentation and collaborative skills. These are all important in the fourth industrial revolution.

IV. CONTRIBUTION OF NEW KNOWLEDGE

There is a dearth of information on the language of engineering education in the fourth industrial revolution and this study has conceptualized what the language of engineering is from various perspectives.

V. CONCLUSION AND RECOMMENDATION

It is no longer arguable that the world we inhabit today is one of discovery and knowledge. Over the last half century, science and technology have come to occupy a critical place as sources of economic growth and social well-being. This has been made possible by engineering education. Engineering education has been a major part of human life and it has evolved from the agrarian age to the industrial revolution. From the creation of simple tools to the complex engineering machineries which abounds now, the journey has been chronicled into series of epoch tagged the industrial revolutions and according to Shawn Cunningham (2018) industrial revolutions are periods in modern human history where innovative technologies are used in ensuring rapid change in the socio-economic condition of people globally. We are at the fourth industrial revolution now and there are varieties of technologies emerging which has the capacity to influence all systems and processes. It was found out that the language of engineering education is mathematics, science and techne and these all have been expatiated on to understand how engineering education is communicated. This study therefore recommends that efforts be intensified on developing the languages in which engineering education is communicated in the fourth industrial revolution. There is also the need for all stakeholders pivotal to engineering education to come to an agreement on what the language of engineering education should be and how it can be communicated further in the fourth industrial revolution.

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