**EXPLORING THE OPPORTUNITIES OF 4TH INDUSTRIAL REVOLUTION TO MAXIMIZE SCIENCE EDUCATION IN NIGERIA**

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**Abstract**

*This work identifies how science education in Nigeria can derive and benefit from numerous opportunities for Information technology and its professionals in the fourth industrial revolution. Likewise, science educationists can beneficially position themselves in the wake of this trend. The term "fourth industrial revolution" is used to collectively refer to a multitude of new technologies that are combining the physical, digital, and biological worlds. This revolution will have an impact on all areas of academic research, as well as economics, companies, education, and even perceptions of what it means to be human. The study also names the Internet of Things, robotics, artificial intelligence, virtual reality, and disruptive technologies as major factors behind the fourth industrial revolution. Professionals with knowledge of artificial intelligence, cyber security, and proactive developers who can construct dynamic systems to fit the digital revolution toward a relevant scientific education are among the skills that would be sought after in this digital economic age. As demonstrated in this work, Nigeria missed out on the first three industrial revolutions and is on the verge of missing out on the fourth. Solutions to avoid this catastrophe are offered, as well as information on the role IT professionals and science educators should play to ensure a smooth transition for the Nigerian educational system, economy, and government into the fourth industrial revolution.*

**Keywords:**  *Artificial Intelligence, Computing, Industrial Revolution, IT Professionals, Science Education,*

**Introduction**

Any society's strengths and weaknesses, both at home and abroad, may be traced back to the efficacy of education (Richard, 2009). According to Richard (2009), education is essential for a society to succeed in contending economically in the global marketplace and is influenced by a variety of interconnected issues, comprising economics, technological improvements in science and industry, and others. Although several nations made contributions to science and technology, education altered throughout the industrial revolution (Yuko, 2016), and this movement revealed the shortcomings of the education system. Auguste Blanqui first used the word "Industrial Revolution" in the eighteenth century, and Arnold Toynbee popularized it. The term simply refers to the economic and social changes brought on by the industrialization process. Every aspect of human life is impacted by this revolution, including socializing, manufacturing, production, and distribution (Aggarwal *et al*, 2009). The industrial revolutions transformed the world with the first being mechanical manufacturing and water power, the second science and mass production, and the third digital technology. According to Klaus Schwab, founder and executive chairman of the World Economic Forum, the fourth industrial revolution originated in 2016 (Marr, 2018). The 4th industrial revolution, also known as Industry 4.0 or 4IR, is the current and developmental transformation in human function caused by disruptive technologies and trends like robotics, IoT, VR, and AI (Rouse, 2017). These disruptive technologies and trends have broken the barriers between the physical, digital, and biological spheres and will affect all disciplines, sectors, and economies, according to Marr (2018). Science education in Nigeria and the globe should concentrate on these disruptive technologies, according to Fisk (2017). They comprise mobile internet, automation of knowledge labour, internet of things, cloud, advanced robotics, autonomous cars, genomics, energy storage, 3D printing, advanced materials, advanced oil and gas exploration, and renewable energy. This research studies how these changes affect scientific education in Nigeria and its effectiveness.

**Historical development of the Industrial Revolution (IR)**

The Industrial Revolution transformed contemporary economies from agrarian and handicraft to industrial and machine-based. The 18th century saw the start of this process in Britain, which then expanded to other regions of the globe. The English economic historian Arnold Toynbee (1852–83), first used the word to characterize Britain's economic growth from 1760 to 1840 (Encylopedia Britannica, 2017), although previous French authors had also used it. In the first industrial revolution, manufacturing was mechanized using water and steam, in the second, mass production was created using electricity, and in the third, production was automated using electronics and information technology. The present fourth industrial revolution is building upon the foundation laid by the previous three industrial revolutions as well as the digital revolution, which has been running strong since the middle of the previous century. This fourth revolution is characterized by the convergence of technology, which blurs the barriers between the physical, digital, and biological domains. This revolution is also characterized by exponential proliferation, which threatens to turn whole global industries on their heads. Because of the depth and magnitude of the complexity of these changes, it may be deduced that the whole production, management, and governance systems have been modified. (Sentryo, 2017).

**Historical Background of Education through the former Industrial Revolutions**

In 1877, J.R. Buchanan stated that education should prepare students for life and “should be like the life to which it prepares” (Barlow, 1967). Concerned individuals had been supporting change and J.H. Pestalozzi, while discussing the Prussian system, emphasized “hands-on” activities rather than on memorization. Pestalozzi emphasized the importance of meaningful experience to train people to be productive (Smith, 2002). According to Aggarwal (2019), up to the middle of the eighteenth century, there were no industries or inter-societal trading and European society was mainly agricultural. Power was found through manual labour and almost all poor children had no education. Since the majority of the population was poor and could not access education, life was centered on farming (Yuko, 2016The first industrial revolution took place when the globe learnt about and began to depend on steam power and machine tools, changing mostly agricultural societies into industrialized ones. Factories began to flourish, scientists and engineers grew more numerous, and a sizable number of polytechnic institutions and schools of applied sciences were formed in all countries that aimed to be civilized and forward-thinking. (Aggarwal, 2019). In 1848, engineering as a discipline and the machine-making industries were still on a small scale. However, the development of railroads, which followed 1848, marked the main advancement in engineering skills. Public education was established, made available to the underprivileged, and the basis for the current educational system was laid. For education, changes recorded are the emergence of work specializations, founding of professional schools and the development of universities (Sakhapov and Absalyamova, 2018). With the introduction of electricity, the growth of transportation, communications, and high-tech industries, the second revolution saw significant advancements in agriculture, manufacturing, and transportation that originated in Britain and spread throughout Europe and the rest of the world (Aggarwal *et al*, 2019). It was a time of expansion for already established sectors as well. STEM was introduced into the workplace, which facilitated improvements in schooling (Aggarwal *et al*, 2019). Foremen, supervisors, and technicians with the necessary skills are in limited supply for these new technologies, according to Richard (2009), who hypothesizes that this is due to inadequate technical education. He adds that it took a while to recognize and create a strategy for technical education and training, which resulted in a long-lasting industrial and economic downturn. Despite this deficiency, technical and scientific institutions were founded at the beginning of the 19th century to train people in higher level technical skills and knowledge, producing a population of technocrats. As a result, the multilevel training system for industry, educational standardization, and the rise in prestige of engineering education were all part of the paradigm changes in education (Sakhapov and Absalyamova, 2018). The third revolution arrived on the globe in the 1950s, and according to Sahin and Tureci (2018), it was propelled by the usage of computers. What is often referred to as the "digital revolution" included the adoption of telecommunications technology, manufacturing automation, and the rapid expansion of services (Sakhapov and Absalyamova, 2018). The rise of semiconductors, mainframe computers, personal computers, and the internet marked the end of the era of mechanical devices and the beginning of a civilization dominated by pervasive digital technology. Power distribution began to change as internet technology and renewable energy started to converge (Rifkin, 2012). Additionally, access to higher education increased as a result of significantly higher diversity on campuses and online technologies' acceleration of academic research's globalization. (Penprase, 2018). As online learning gained popularity, instructors were introduced into a world of learning where knowledge is readily available and generally inexpensive. The necessity for an interdisciplinary curriculum that incorporates liberal arts and interpersonal skills training was stressed throughout the reform of STEM education. The developments that had an impact on engineering education were the integration and globalization of education, the increase in academic mobility, the conversion to international education standards, and the training of service experts.

# Nigeria and the potential of 4th industrial revolution

Since the start of the first Industrial Revolution in the 18th century, there have been a total of four significant industrial eras. As they are more often referred to as, "cyber-physical systems" are characterized by a technological fusion that obfuscates the boundaries between the physical, digital, and biological domains. Between its technical potential and the required political agenda, Nigeria must bridge the gap. Nigeria must focus on examining cutting-edge tactics that are being tried and tested in to benefit from technological improvement on a global scale. The Fourth Industrial Revolution is spreading swiftly, and it has never been more important for significant stakeholders to be involved. To profit from evolving technologies while preserving trust, the government, businesses, and people must work together. The "digital divide" refers to the disparity between individuals, groups, or organizations in Nigeria with regard to their access to urban internet connections or to ICT infrastructure in general. Nigeria's widening digital gap is a result of several issues, including education, a lack of electrical infrastructure, money, urbanization, a number of other social and political variables, and a number of others. Nigeria's young generations must learn digital skills to face the challenge posed by the digitalization of the job market, and policymakers at both the local and national levels must take responsibility for this endeavour. Accelerating Nigeria's digital development is a significant challenge. We must be ready for the next fourth technology revolution by increasing our country's digital growth.

We need a more contemporary state that promotes the use of new technologies if we are to better people's lives and progress knowledge, development, welfare, and trade. To do this, we must set into motion a future agenda that pushes the state to make the transition to digital with the aid of modern infrastructure, regulations, and educational programmes. During the First Industrial Revolution, Nigeria was overlooked. According to general opinion, this occurred when humans started using fossil fuels and mechanical power as major sources of energy instead of biomass, human labour, and animals. The Second Industrial Revolution, which took place in the latter two decades of the 19th and the first two of the 20th centuries, did not take place in Nigeria. It led to important developments in the transmission of electrical energy, cable and wireless communication, the synthesis of ammonia, and new strategies for power production. Nigeria was excluded from the Third Industrial Revolution, which started in the 1950s and was characterized by the development of digital systems, communication, and significant increases in computer power. The Fourth Industrial Revolution, which is the creation of "cyber-physical systems" requiring whole new capabilities for humans and machines, is something Nigeria is set to lose out on. This is a result of those pushing for restructuring concentrating on the machinery of the first industrial revolution of the twenty-first century. Although these abilities depend on the tools and systems of the Third Industrial Revolution, the Fourth Industrial Revolution heralds’ whole new ways that technology will be incorporated into society and even human bodies. Examples include new applications of AI, cutting-edge materials, gene editing, and governance models that depend on cryptographic technologies like the blockchain.

The restructuring supporters in Nigeria have lost sight of this progress because they are focusing on the country's 36 states, 774 local governments, and its natural riches rather than paying attention to the fourth industrial revolution. They are basing their claims on the local management of resources, which is in line with the first industrial revolution of the twenty-first century. The meaning of schools and learning has drastically shifted in recent years, borderless learning is posing a challenge to conventional brick and mortar schools, and educational curricula must swiftly adapt to the new conditions. As a result, Nigeria demands innovations to keep up with the rapid pace of change. The most valuable educational resource in the world now belongs to the Internet, which has surpassed the value of conventional classrooms. It does not have any physical borders, and there are no walls either. People who have received degrees and certificates from universities and other organizations located in locations that they have not yet been to fetching commonplace in our immediate environment. Because the United States is now preparing students for jobs that have not yet been established and using technology that has not yet been found to solve issues that have not yet been recognized as problems, Nigeria needs innovations because the top 10 most in-demand vocations in 2010 did not exist at all in 2004; because the United States is currently training students for jobs that have not yet been created to address issues that have not yet been identified as problems. As a nation, need innovations because the information age, which we are now a part of, requires us to better prepare our children to compete against individuals from all over the globe. That responsibility is owed to them by us. Due to the thinning of international borders and the emergence of a genuinely global community, innovations are required. When it comes to matters of commerce, we do not now compete against our locals or fellow citizens; rather, we do so against unnamed parties located in other countries. It is normal practice to hunt for talent and expertise across international borders. Our children will have to compete with children from China, India, Ghana, the United States of America, South Africa, and a great number of other countries for work and opportunities. We need to remodel our schools to develop a new learning culture, increase educational expenditure, examine our curriculum, and offer our children the skills they need to address challenges in the real world, which is why Nigeria needs innovations. Nigeria requires innovations to adequately describe and agree on the kind of communities and societies we should live in for the next five, ten, twenty, and fifty years. What kind of material, financial, and human resources are needed to realize our vision? What location do we want to see our people? Innovations are also required to examine our educational curricula in favour of the skills and abilities that the current world requires. Nigeria needs innovations that will develop leaders in a variety of fields, including technology, innovation, energy, power, agriculture, genetic engineering, banking and finance, environmental management, climatology, artificial intelligence, medicine, sports, entertainment, and the arts. Although it has rescued us, oil is running out. The fourth industrial revolution, which will increase people's mental capacities, their ability to perceive, their ability to create, and their ability to contribute to the world, will power the next wave of progress. For this reason, we must make significant investments in 21st century education. Every student in today's schools should have access to a computer since they are not toys.

The Internet offers a platform for knowledge and information to grow exponentially, helping our children develop the skills they need to solve problems in the real world. Not only Facebook, WhatsApp, Instagram, and Snapchat are included. We must begin educating our children on how to code and write programs at a very early age so that they can develop technology fixes for issues that are particular to our planet and others. The STEM fields of science, technology, engineering, and math should be arranged as a result. First, since technology is a crucial resource in the information era, coding and programming skills have become in-demand skills. Nigeria needs innovations to take advantage of new opportunities and empower our youth to explore unknown terrain. Nigeria also needs innovations if it wants to foster the growth of visionary leadership and flexible, creative knowledge. Innovation is a fundamental element of economic competitiveness and progress in the fourth industrial revolution.

**Industry 4.0 and its Implications for Science Education**

There is little doubt that the Fourth Industrial Revolution's technologies will bring about significant and quick change, but it is yet unclear what precise effects they will have on people and the environment. Given the potential for an irreversible loss of control over networks of potent AI agents with growing autonomy within the financial sectors and the urban infrastructure, higher education must act quickly to prevent irreparable harm to the environment or to positively influence social dynamics. Higher education must react quickly to take action since technology has the potential to have both substantial social effects and disastrous environmental effects. It has been suggested by Sakhapov and Absalyamova (2018) that the fourth industrial revolution has already started due to technological advancements in the Internet of Things, the incorporation of cyber-physical systems into manufacturing, and neuronet. This indicates that education will become more individualized and virtualized, that projects will become more interdisciplinary and multidisciplinary, and that educational resources will interact. Engineering, a branch of science, is the skill of applying scientific and mathematical principles to design, develop, and operate structures, machines, materials, systems, and software, as well as to maintain them to address a specific challenge for a specific purpose, according to Jeganathan et al. (2018). Because engineers are necessary for the development of these cutting-edge technologies and applications, a revamped educational system for engineers is very necessary during this period. Because of globalization, engineering is no longer practised in its traditional regional settings (Hoffman, 2017). Today, it is expected of an engineer to be able to solve problems, to be imaginative and practically astute, to uphold professional and ethical standards, to be an effective communicator, to demonstrate skills in leadership, business, and management, to be resilient and dynamic, to be adaptable, and to have a global perspective. According to Hoffman (2017), engineers are responsible for: the cornerstone of a strong economy and a prosperous society. According to Adams (2018), there are two effects of Industry 4.0. The first is that academics and scientists must do research and make interventions to make artificial intelligence helpful for society as a whole rather than simply as an industrial tool. Considering that most present AI systems are built on American and European conventions, this entails rethinking AI.

A revolution in teaching and learning techniques is required to adopt a form of learning outcome based on skills, merging academic and vocational education to meet the market requirement, taking into account the dynamic changes in society (Dabbagh, 2018). The teaching and learning processes should now take into account Educational Technology (EDUTECH) services, lifelong learning routes, digital fluency and STEM skills, 21st century curriculum, and educational innovations are among sthe areas that are being prioritized. (Adams, 2018). The curriculum should also be decolonized. Engineering education and practice should be completely reoriented as a result of this shift in curriculum. The curriculum should now take into account technical sustainability and concentrate research on innovations that have a direct influence on sustainable development, the provision of assistance in formulating policy, and the spread of sustainable technology. Dabbagh (2018) goes on to say that task-based learning, project-based learning, problem-based learning, competency-based learning, and case study approaches should all be included in the curriculum to make it more market-responsive and student-centered. It would make sense to make significant adjustments to the science and technology curricula to help students acquire their skills more quickly in the emerging fields of data science, robotics, artificial intelligence, nanomaterial, and genomics. The old "primary" sciences, such as physics, biology, and chemistry, would be revised in such a Fourth Industrial Revolution STEM curriculum, and training in computer science disciplines would be prioritized as a means of Fourth Industrial Revolution literacy.

To explore emerging disciplines like molecular design and synthetic biology, new techniques in biology can include training in beginning courses. Students at Stanford University are required to design treatments for real-world pathogens like HIV and Lyme disease using data derived from experiment planning and scientific literature (Cyert, 2017). In a brand-new Engineering Biology course, students may "bio-print" their living forms on computers to address issues in the real world. Stanford University is another location where life science has been altered. There, students are forced to create cures for actual illnesses like HIV and Lyme sickness. These programmes are being implemented as a reaction to the expanding bio-economy, which is presently valued at over $400 billion in the United States alone (Endy, 2016). At Stanford, students may now choose to major in bioengineering, which is a recently introduced field of study. Educating students at the "interface of life sciences and engineering" (Abate, 2015), combines the expertise and resources of the departments of Engineering, Biology, and Medicine. Along the same lines, advancements in chemistry include the proliferation of degree programmes and courses in "Green Chemistry," an interdisciplinary field that brings together chemistry, environmental science, and related fields. Science, and biology engage students in real-world environmental issues like toxicology, bioplastics, and synthetic fuels and teach them pollution control methods. A new physics curriculum emphasizing teamwork skills for the Fourth Industrial Revolution is now being created. The curriculum focuses on group projects in which students create unique musical instruments, cryptography devices, and other innovations (Perry, 2013). To provide more effectively trained workers to help advance and accelerate the development of ever-more complex Artificial Intelligence, Biotechnology, and Nanotechnology, more educational responses to Industry 4.0 would be to retool STEM institutions and curricula to provide new departments and science programmes in new interdisciplinary fields.

Infrastructure changes must be prioritized if engineering education is to be effective in the modern day. One example of this is the conversion of conventional teaching laboratories into "maker spaces" (Hoffman, 2017). The Third Industrial Revolution, which resulted in the creation of hybrid online and in-person instruction, the successful and seamless integration of global video conferencing, as well as a wealth of asynchronous educational resources, must be the cornerstone of any engineering educational strategy for industry 4.0 because it brought about the development of hybrid online and in-person instruction, the effective and seamless integration of global video conferencing, as well as a wealth of asynchronous educational resources. Additionally, education has to be reorganized to be everlasting to continue professional growth. This is because Industry 4.0 is changing and will continue to disrupt all social areas, making it unnecessary for academics to have the necessary knowledge or abilities to adopt, manage, and collaborate with the new technology (Adam, 2018). Adam (2018) goes on to say that students studying fundamental and applied sciences should have a basic understanding of artificial intelligence and the current state of the world's social and political structure. This brings up a further issue, namely the ongoing redefining of the technical employment market in this 4.0 age. The dean of the University of South Wales, Professor Mark Hoffman, asserts that "almost every nation is facing a lack of engineering talents in one way or another. The Industry is looking for a whole different kind of engineer, and IT is an area of engineering in and of itself (Hoffman, 2017). According to Garg (2017), today's engineering students are well aware of and interested in these careers since scientists are among the most sought-after and well-paid professions in the world. Formerly a research topic, artificial intelligence is now prepared to be included in the engineering curriculum. Many Western countries have already adopted this policy, and Africa should do the same. According to Adam (2018), the work market is changing at an accelerating rate. He further claims that many occupations will vanish and that many positions that are not yet defined will replace them. The younger generation should be well prepared with knowledge and hands-on experience in these subjects. Dabbagh (2018) compiled a list of potential STEM careers and educational prospects, including software development, data mining, and automation. Mathematics, quantum physics, computer engineering, and automation are at the top of the list. As a result, science students should now be taught how to be entrepreneurs to broaden their perspectives beyond just the technical aspects of science and enable them to manage businesses, markets, and society as a whole (Hoffman, 2017). According to Dabbagh (2018), educating scientific students should focus on cultivating questioning mindsets and attitudes as well as knowledge and technical abilities. This is crucial because it will enable students to perform effectively in the modern, flexible, and dynamic workplace. The development of skills via technical and trade colleges was the emphasis of engineering education in the first half of the 20th century.

**Challenges for Education**

Professor Klaus Schwab believes that a technology revolution is on the horizon that will radically change the way we live, work, and interact with one another. The transformation will be unlike anything that humanity has ever gone through in terms of magnitude, breadth, and complexity. Even while we are unsure of the exact course it will take, one thing is for certain: everyone who is a part of the global political system, from the public and commercial sectors to academia and civil society, must actively participate in the reaction. All of the public and private sectors, as well as academia and civil society, are included in this. This clarifies some of the challenges brought on by the Fourth Industrial Revolution. According to Peters (2017), the growth of global industries at this time of the fourth industrial revolution is both exciting and alarming, which further demonstrates the extent of the problems and the breadth of the required solution. Life will change as a result of 3D printing, the Internet of Things, and other technologies. Industry 4.0 may boost income levels by empowering company owners to "run" with their creative ideas. It will raise many people's standard of living globally. The 4.0 has many advantages, but there are also a lot of significant problems that still need to be overcome. To start, given its potential to disrupt labour markets, the revolution may result in more inequality. As technology continues to replace human labour across the board in the economy, there is a possibility that the gap between the returns on capital and the returns on labour may expand. In this era of digital technology, regular money and regular labour will not be the resource that is considered to be the most valuable or the scarcest. Instead, the people who will be successful are going to be those who can come up with fresh, innovative ideas. In the not too distant future, capital will not be as vital for manufacturing as skill will be. The most in-demand resource will be engineers with ideas rather than investors or labour. (2014) Brynjolfsson, McAfee, and Spence.

Tim Cook, CEO of Apple, said at the 2017 Bloomberg Global Business Forum: "If I were a country leader, my goal would be to monopolize the world's talent" (Leswing, 2017). A progressively split employment market may result from the struggle for ability. Low-skilled, low-paying employment will be replaced by computers and digitalization. Less likely to be replaced are positions with greater salaries but more complex work requirements. Social conflicts may rise as a consequence of this greater dichotomization. Schools find it difficult to maintain the same pace with the Fourth Industrial Revolution's rapid technological advancement. Teachers will need to modify the teaching and learning process to reflect these capabilities since there will be competition among workers who possess the necessary abilities to deal with the new technology (Adam, 2018). It will be necessary for institutions to employ highly qualified and skilled faculty to teach students to be specialists; this will cost a lot of money (Gary, 2017). Since of this, there will be a disruption in the labour market since students won't be prepared to handle it if policymakers are not truly savvy in making the appropriate judgments with the desire to have them executed. Therefore, student must learn how to work with machines rather than against them, how to program machines as opposed to allowing them to do so. One of education's biggest issues would be how to respond to this since it would need rethinking pedagogical quirks and teaching methods in higher education. Industry 4.0 poses a huge danger of employment shift, but there are also many additional difficulties, including risk aversion, hacking, and cyber security (Lambert 2017). This issue will have an equal impact on schools, which will continually need to update their curricula to be able to handle problems with cyber security so that businesses can remain secure. A greater degree of vigilance is increased when our lives get excessively too tied to our various electronics, including our smart speakers, autos, light switches, and mobile phones. One of the main themes in 2018 consumer electronics was the idea that there is no turning back once everything is linked (Goode, 2018).

**Conclusion**

The fourth industrial revolution is reshaping society and requiring a whole new breed of engineers. As a result, science and engineering education will need to evolve in the same way. Because this profession faces issues that will decide its future and because choices taken in this period will form this future, science and engineering education in Industry 4.0 will need to develop scientists and engineers to satisfy future needs. The following suggestions are made as a result of the study's revelation of the difficulties and ramifications that science and engineering education will confront.

**Recommendations**

To better educate future engineers for the flexibility, critical thinking, and creative abilities required, as well as possibilities in innovative and value-adding ways, engineering education and training institutions must evolve. Therefore, it ought to be taken advantage of to create a strategic vision for the future. STEM education has to be restructured, and STEM centres should have access to qualified STEM experts and resources that will result in STEM graduates with 21st-century capabilities. In engineering programs, with the aim to promote applied engineering together with innovation, and design, all the way to commercialization and entrepreneurship, a multidisciplinary organization should be created. Modern techniques should be used in engineering education, and engineering faculty should encourage education-related research. Engineering faculty must be taught the necessary teaching and learning approaches and professional skills that their students will confront in the industry as engineering education advances to meet changes in technology, markets, and social requirements. Employers are searching for engineers with the capacity to work in multidisciplinary teams, entrepreneurship, leadership, and lifelong learning abilities. They also want engineers who will use interdisciplinary knowledge in their jobs. To address them, engineering educators should enhance and regularly update their abilities while also training their pupils. Engineers who get environmental education will engage with society more effectively and have the necessary knowledge and abilities to address broad world concerns.

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