

Engineering Education and Power: the Case of Innovation in the 21st Century

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Abstract: *Engineering education is the application of scientific, economic, social and practical knowledge to invent, create, design, build, maintain, research and improve structures machines, devices, systems, materials and processes. Engineering education is therefore an important component of innovation. The various innovations brought about by engineering education has delineated various countries along the lines of power and there is a dichotomy between them. Key among this is the separation between the Global North and the Global South. Innovation is a process and application of a new or meaningfully amended creation that needs long term commitment, resources and innovative climate in an organization. Findings from the study revealed that power dynamics is present in all situation and it takes different forms. It influences and shapes relationship. The study therefore recommends that there is a need to intensify efforts on engineering education in developing countries to create more innovations in the 21st century and effort should be geared towards the use and application of these innovations.*

Keywords: *engineering, engineering education, power, innovation*

I. INTRODUCTION

Engineering according to the Royal Society of Engineers was defined as the application of scientific, economic, social and practical knowledge to invent, create, design, build, maintain, research and improve structures machines, devices, systems, materials and processes. Engineering education is therefore an important component of innovation. As societies developed and began to gain more mastery of their environment, the need to develop simple machineries came to the fore which made engineering education an essential discipline vital to the sustenance of life. This led to the development of various tools and machineries which has facilitated and eased production processes. This process has gained more traction as more investments were made in human capital between various countries of the world. The various innovations brought about by engineering education has delineated various countries along the lines of power and there is a dichotomy between them. Key among this is the separation between the Global North and the Global South. As nations began to develop more and they leveraged on engineering education, they became more powerful. This has been the basis for the differences and separation of powers between various countries of the world. Power according to Obisi (2003) was defined as the capacity of A to influence the behavior of B to do things he or she would not otherwise do. It has been observed that the typical engineer that is produced from today's university does not have all the requisite skills necessary to create innovative solutions for the public (Galloway, 2004).

These dearth of necessary skills has been a major bane to leveraging on the ideals and power behind engineering education. Innovation is a process and application of a new or meaningfully amended creation (OECD, 2005) that needs long term commitment, resources and innovative climate in an organization (Badran 2007; Utterback, 2002). Innovation can only be worthwhile when there is network of interdisciplinary members, appropriate methods and requisite financial opportunities to maintain it (Haynes, 2002). Innovation also needs adequate planning, long term focus and orientation and infusion of technologies (Utterback, 2002) which engineering education provides. This typifies that for innovation to be worthwhile, there must be a fusion of various elements with technology at the center. Not only that, innovation doesn't just happen, it goes through various processes. To understand how innovation in engineering education has brought about power, some countries of the world that are reputable for various innovations will be considered and various evidences of these innovations which conferred power on them will be considered. This study will conceptualize power and its dynamics and make the case for innovation in the 21st century.

II. METHODOLOGY

This study is a theoretical discourse which seeks to shed light on engineering education and power using evidences of innovation in the 21st. The study relied on evidences from literature to conceptualize power and its dynamics and to understand innovation in the 21st century. The study made the case for how innovation in engineering education in the 21st century has conferred power on some countries of the world.

III. CONCEPTUALIZING POWER AND ITS DYNAMICS

Power dynamics is present in all situation and it takes different forms. Take for instance, a relationship between a professor and his student, parent to child, boss to employee, politicians to citizens, husband to wife, religious leaders to adherents etc. in such relationship, by certain degree of differences in people be it in knowledge, resources, experience, age, and gender, it has separated people into various classes where one appears by evidences of superiority to be higher than others and this he exerts on his inferiors. Understanding power and its various dimensions is important in knowing how influence is exerted on others in some of the relationships stated above.

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Power is a concept that has various meaning and wide application depending on context. According to the Merriam Webster dictionary (2020), power was defined in various ways which I will quickly consider. Power is the ability to produce an effect. This definition implies that power has the potency to influence and cause an effect. It was also defined as a legal or official authority, capacity or right. This definition typifies that power can be conferred on the basis of legislation, office, capacity built over time or individual and fundamental right. Power was also defined as the possession of control, authority or influence over others. It might also mean physical might, mental or moral efficacy, political control or influence. Taking a diversion from the approach used in defining power above, it was revealed that power is the source or means of supplying energy especially electricity or the time rate at which work is done or energy is emitted and transferred. These definitions have shed light on what power is following various dimensions but for the purpose of this study, I will conceptualize power using evidences from scientific literatures.

Weber M (1947) a renowned sociologist, philosopher and political economist gave his definition of power and he observed that power is the probability that an individual can perpetuate his/her own will without any rebuff or resistance. This definition highlights the enormity and degree of influence power wields. It might be individual or national. For instance, some acts might be perpetuated by certain individuals as a result of their position or influence and they might go scot free. This might give them a push to perpetuate same without resistance in the future. This applies to nations of the world to when they take certain dangerous position which might be overlooked without any resistance from others. This doesn't just happen except there is influence to be exerted in getting out of the situation.

Mechanic (1962) gave the definition of power and power was defined as a force that results in a behavior that would not have initially occurred if the forces were not present. This definition by Mechanic emphasizes the import of some forces critical to exercising power on people or in a place. Like I mentioned above, there are elements that are necessary for power to be exerted and they include resources, energy, information etc. with people and nations of the world having unequal access to these elements, their grasp and influence on power is characterized by differences. However, in some cases, if the elements are available, some countries might still not assume a position of power due to some reasons. Poor ability to harness such factors might be a veritable reason for some people or nation not to assume power. Corruption is also another critical factor that can affect people from gaining power. Systemic failure and government poor performance might also be a major factor that can affect assumption of power.

The roles people assume typifies their attitude towards other people and in such situation they are viewed as having power. The way we view others is also a reflection of how we view ourselves. Power when gotten can be to some ends. With good use of power, it leads to achieving preconceived goals and objectives while poor use of power can cause failure in a system. Failure to use power also has consequences on whom the power is to be exerted

on and it can make the recipients defective. Humans are social animals and at all time, they must be guided. No one has the monopoly of individual supremacy in that in one situation or circumstance, he/she must defer to someone higher in hierarchy.

The right application of power has brought about tremendous changes globally and let's consider for instance political power. Countries where their leaders who have been saddled with the power to rule does things right, it has paid dividends for the citizens. Take for instance, the United States of America. Governance there has always been for the people and this has been manifested in policies that seeks to better the welfare and condition of people. In contrast, take a look at some developing countries, leadership there has been a tool for personal ambition and individual aggrandizement. This has resulted into poor consequences like development, inadequate infrastructure, widespread poverty, prevalence of diseases etc. Also, a delineation between countries of the world into Global North and Global South has revealed how leadership can widen the divide between people.

One characterized by massive development, high investment in technology, high literacy level, good infrastructure and low poverty, reliance on secondary and tertiary means of production, strong institutions. The other characterized by widespread poverty, poor development, hunger and sickness, inadequate infrastructure, low literacy level, reliance on primary production, weak institutions and corruption. This typifies the distinction between good and poor use of power. It also reveals that power has in it enormous ability to affect the lives of others. In whatever dimension, it is wielded, it has influence on people, groups, territories and even nations of the world. What could be more Disheartening is how power has been a tool in the wrong hands which has been used for personal purposes and it has consequences on those its exerted on. The impetus is to understand that power is intangible yet its use or misuse has tangible consequences which can be seen by all. In all facet of life, power is exerted as shown and with its exertion comes consequences.

IV. DECONSTRUCTING INNOVATION IN THE 21ST CENTURY

In line with international practice, innovation can be likened to a new or improved product or process (or both) that is unlike the old product or processes and has been accessible to potential users (product) or incorporated into use in a unit (process) (OECD/Eurostat, 2018). This definition of innovation shows the novelty and newness dimension of innovation. It is a change in existing structure and processes which influences a product or a process. It is vital to note that innovation according to OECD/Eurostat (2018) was categorized into two which are product innovation and process innovation. Product innovation can be likened to innovation made on goods and services whereas process innovation is innovation made on production processes.



This implies that all activities in an institution which starts from the use of all elements of production to the final output of goods and services can be referred to as process innovation. It can include organizational process, policies and strategies that influences activities in the organization, procedures etc. It is important to note from the definition above that innovation can be tangible and intangible which has significant consequences. Like it was revealed above, having a new or improved product typifies the tangible dimension of innovation. A situation wherein a physical product is made better. This can only be made possible by the apparatuses of engineering education. One of the definitions of engineering that has profound relation with this dimension is one given by the Royal Academy of engineering where engineering was defined as the application of scientific, economic, social and practical knowledge to invent, create, design, build, maintain, research and improve structures machines, devices, systems, materials and processes. The other dimension is the intangible scenario where there is a complete overhaul or improvement in a process. It might be the conduct, structure and mode of operation existing in a system in time past. This might be influenced by the need for better processes, the need to keep up with time, increase capacity, exposure, access to resources, personal decision to make a process better, economic, social and environmental conditions can all influence the innovation process.

Innovation according to OECD (2005) is the process, the application of a new of meaningfully corrected method that requires long term commitment, resources and innovative environment within a context (Badran 2007; Utterback 2002). This Implies that there is a novelty dimension to innovation and more than that, previous ways of doing things can be amended if there are better ways to do it. Also, within the purview of this definition of innovation, there is a need to understand that innovation might not be sudden. It requires long term commitment which can only be brought about by series of processes and mental exercises about ways in which a process can be made better. Not only that, for innovation to be made possible, there is the need for resources and a climate conducive for innovation. Resources are expended in all situation and they are vital in ensuring that any innovative process is worthwhile. What this means is that in the drive to make a process or a system better, one cannot do without expending resources. The import of innovative climate cannot be trivialized as it is vital in the innovation chain. With indices such as educational or literacy level, cadre of people involved in a process, general literacy level, it might influence the pace at which innovation take place. In innovation, the pace at which people adopt is always different and this might be influenced by some of the factors described above. Innovation is vital in ensuring sustainable long-run productivity growth for countries of the world. For nations that are farther from technologies made possible by engineering education, they can only have catch-up growth. For leading economies like the United States, Japans and some nations from the West, long-run productivity brought about by stimulating technological innovation should be encouraged. One of the factors that contribute to innovation is research and development. It was revealed in 2015 that

spending on research and development (R &D) in the United States went over \$495billion (National Science Board, 2018) which shows that the expenditure on research and development has been on the increase since 1953. So also is spending on research and development that is funded by businesses, the federal government and other institutions. As a share of the Gross Domestic Product (GDP), spending on research and development increase from 1.3percent in 1953 to around 2.7percent in 2015. Various countries of the world have made investment into research and development at different paces and this has been a distinguishing marker for delineating between nations on indices of development. This has also made distinction possible along the Global North and the Global South. Innovation is important in all dimension as it proffers new ways of doing things and also seek to make better old ways that might not be working effectively.

Understanding how engineering education through innovation confers power in the 21st century

With various innovations in the 21st century, various developments have come to the fore manifested in giant architectures, better means of production, improved infrastructures, better means of living and so many other benefits. This has come with it series of advantages and benefits for humans globally. The pace and velocity with which innovation emerged in the 21st century can be attributed to the fourth industrial revolution. The fourth industrial revolution has with it some innovations in the 21st century which include autonomous and driverless cars, 3D and 5D printing, robotics and automation, block chain, augmented and virtual reality, MOOCs, the capsule endoscopy, bitcoin and cryptocurrencies, mobile operating systems, gene editing/CRISPR, the internet of things, genetic engineering, social media, blue tooth's, fiber optics etc. These innovations have definitely had an effect on all systems of production as revealed by Klaus Schwab (2015) that there will be new ways of serving existing needs will be created. Business models are influenced by the fourth industrial revolution and this has resulted to new manufacturing patterns and new method of communication in the supply chain (Glova et al, 2014). The pattern of manufacturing and the means of manufacturing are from engineering educations. Engineers designs and creates various devices that are important for manufacturing and other industrial processes. By rapid development brought about by innovation in the 21st century, various countries of the world have leveraged on the strength and ingenuity of engineering education to become top brokers of power amongst the comity of nations. With engineering education being a major driver of development which is manifested in various epoch of human evolution captured in the first industrial revolution to the current fourth industrial revolution. Innovation was captured in the move from simple means of production powered by steam and water to drive mechanical engines to electricity to information and communication technologies and now to a fusion of physical, biological and cyber physical technologies.

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These has had attendant effect on nations of the world in terms of power. The United States News & World Report uses various sets of criteria to assess power rankings globally and some of these factors include leadership, economic influence, political influence, strong international alliances and strong military alliances.

The United States which is perceived to be the most powerful country was on top of the list and it has the

largest economy and biggest military budget with more than \$649billion spent on military hardware and personnel in 2018. United states have assumed a leadership position in the war against terrorism and the country is the biggest contributor to NATO and it forges alliances by donating billions of dollars in military aids to nations of the world. It was reported in 2017 that the United States spent more than \$35billion in economic aid and \$15billion in military aid.

Ranking	Country	Population	GDP(\$)
1	United states	327.2million	20.5trillio
2	Russia	144.5million	1.7trillion
3	China	1.4billion	13.6trillion
4	Germany	82.9million	4.0trillion
5	United Kingdom	66.5million	2.8trillion
6	France	67.0million	2.8trillion
7	japan	126.5million	5.0trillion
8	Israel	8.9million	369.7billio
9	South Korea	51.6million	1.6trillion
10	Saudi Arabia	33.7million	782.5billio

Source: <https://www.usnews.com/news/best-countries/power-rankings#united-states>

Russian and china which are the next two countries in terms of power are among the world top four military spenders. Russia and china expends huge financial costs on their military. This has made them assume a position of power. Next is Germany, the United Kingdom, France and japan. They are large economies and they expend much more on international aid. Israel as the number eight on the spot spends more on military than the United States while South Korea and Saudi araba took the 9th and 10th position respectively.

The United States as the most powerful nation has made lots of innovation and as revealed by OECD/Eurostat (2018) business innovation is the implementation of a new product or improved product or business process that is significantly different from previous products and processes and has been introduced into the market or used by the firm. Some of the innovations in the United states is investment in intangibles and according to WIPO (2019) intellectual property which stems from knowledge and creative enterprise are literary and artistic works which include symbols, images and names used in commerce. They create benefit for years to come and some of them include computer software, research and development, design and artistic creation etc. digitization is also the use of many intangible tools in different locations with the aid of tangible tools. Between 2007 and 2017, the United States raised their annual investment in three intangibles namely computer software, research and development and artistic originals by almost 50% to \$796billion (Science and engineering indicators, 2019).

It was observed that between 2014 and 2016, about 17% of US firms introduced an innovation. That is, a new or

improved product or process. Some of the highest innovations made in the United states was in industries that produce products and services for the digital economy through information and communication technologies (ICT), both within and outside of the manufacturing sector, have some of the highest innovation rates. For example, innovations were reported by 61% of software publishing companies, 53% of computer and electronic products manufacturing companies, and 47% of data processing and hosting companies (Figure 1). Industries that produce health-related products and technologies also report above-average innovation rates, including medical equipment and supplies (44%), chemicals (45%), and scientific R&D services (43%). Companies that produced navigational, medical, and other instruments, under the broader computer and electronic products industry category, also report an above average innovation rate (60%). These all would not have been possible without engineering education. It has also been a major factor for power in the United States.

Global venture capital investment, measured in current dollars, soared significantly to \$271 billion in 2018 which was more than a 50% increase over the 2017 total and nearly four times as high as its level 5 years ago. Over the last decade, the venture capital market has shifted from a U.S.-centric structure toward a more globalized market with the Asian region, primarily China, as a rapidly growing recipient of investment. As the leading recipient country of venture capital investment in 2018, the United States received 44% (\$119 billion) of total global venture capital. (Pitchbook, 2019).



U.S. companies reporting product or process innovation, by selected industry: 2014–16

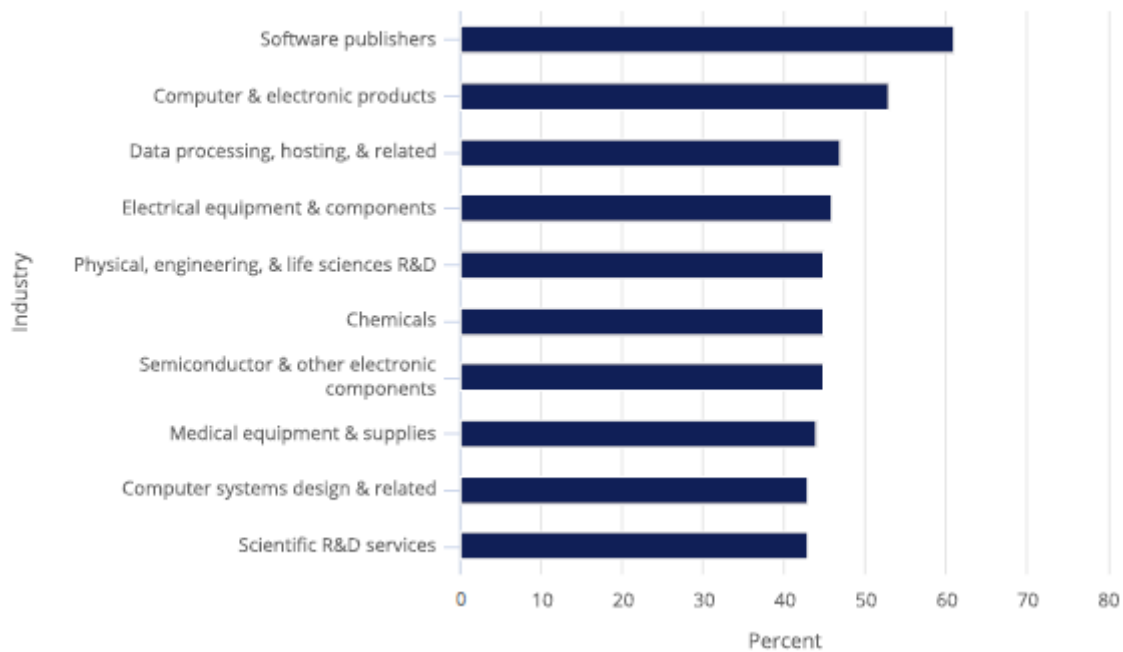


Figure 1

Note(s)

Electrical equipment includes appliances. Physical, engineering, and life sciences R&D excludes biotechnology.

Source(s)

NCSES, 2016 BRDIS. *Indicators 2020: Innovation*

Data on venture capital investment show emerging areas where investors see potential commercial impacts. In 2018, most of the global venture capital funds were received by the United States (44%) and China (36%). In the United States, venture capital is focused primarily in areas that rely on software, including mobile technologies, AI, big data, industrials, and financial technology. Among these technologies, AI investment grew the most since 2013. AI technologies include machine learning, autonomous robotics and vehicles, computable statistics, computer vision, language processing, virtual agents, and neural networks. In China, ICT, which includes software, accounted for slightly more than half of total investment. One problem with Russian government support for research and development is that it has not prompted an accompanying surge in private funding. In Russia private support for research and development, as a share of the GDP, hardly matches that of Germany, the United States, and France (Global R&D funding forecast, 2016). Specifically, Russia falls far short behind the United States.

Germany has been an innovative country and the country has contributed much to science and technology. From the manufacture of cars and consumer products, Germany is a world leader in innovation. This has been made possible by the presence of leading universities and research institutes with major focus on engineering, IT and manufacturing industries. During most periods in the 20th century, Germany could boast of more Nobel prize scientists than any other nation and output from German scientific endeavor are classified among the best in the world. Some of the 21st century innovation in Germany include Flexnet which is a

VDI/VDE innovation and technique which develops new materials, devices and systems and it aims to make Europe a world leader in flexible, organic and large area electronics. Also, SMERobotics has the aim of developing new manufacturing robot that is characterized by simplicity and intuition. E-brain is also an innovation which is like a new Nano-scale sensor for ambient living applications. Diamant which is an innovation by the University of Ulm is predicated on technologies that can engineer materials at the level of single atoms. Smartcode is an innovation for smart energy management in buildings and neighborhoods (European Commission, 2012)

The United Kingdom has also been a leading figure in innovation globally and a research by scientists from Queen's University Belfast on ionic liquid chemistry has been named the 'Most Important British Innovation of the 21st Century'. (Queen's University Belfast, 2013). This is among the series of innovation from the United Kingdom in the 21st century. France has introduced many innovations that has profound impact on the world. The first electric airbus, robots on a budget, tobacco free hookah, humanoid robot, foldable helmet, plume a gadget that connects to your phone and measures pollution in the air, robotic toy for autistic children, automatic tattoos etc. (thelocal.fr, 2020)

Japan has been a major epicenter for innovation in the technological landscape and the laptop Toshiba was first produce for a mass market in Japan.



The emoji used in emails and chats are Japanese innovation. As reported by Forbes, Japan is home to 10% of the world's innovative companies. And yet Japan's creative dexterity is all too often minimized, with the focus on places like Silicon Valley or Tel Aviv. With the production of the bullet train, the Walkman and the blue LED, Japan can boast of new innovations. Some of the new innovations are introduction of 8K era 27inch monitor, Gundam Concierge Haro which was a robot, bitescan to determine a user's bite speed, number of bites and type of bite by using a waveform detected at the back of the ear, earpiece to replace the fingerprint, factory robots, calorie scanner that uses infrared signals to measure the nutrients of a meal, supermarkets of tomorrow (Uscokets) which uses real time data to manage a store, digital makeover, the perfect baby sitter, Qoobo therapy robot etc (Jenni Marsh, 2018)

Israel is a country reputable for innovations in technology. According to a recent knowledge Wharton article, it ranks second only to China as a foreign nation with the largest number of NASDAQ-listed high-tech companies. Wharton professors Jerry Wind and David Reibstein emphasized during the recent Wharton alumni webinar "Israel Innovation for Global Social Impact" that Israel's innovation is not only in cellphones and servers. Israel has developed an extensive and growing pipeline of innovations for global social impact in the areas of food, water, energy and health care." Focusing on innovations that address major societal problems around the world is a smart innovation strategy and good business," said Wind, who is the Lauder Professor and director of the SEI Center for Advanced Studies in Management. Some of the innovative organizations and their products showcased were: Netafim, a company that has created a system to monitor, manage and distribute water, fertilizer and pesticides to enhance agricultural production; TAMA, which has created a film to cover and preserve hay and has already distributed its product to farmers around the world; Jewish Heart for Africa, an organization that brings Israeli technologies that enhance energy, water purification, health care and nutrition to African villages; and TEVA, the world's largest generic pharmaceutical company.

Korea's industrialization evolved from imitation to innovation. In the initial stage, Korean industries attained technological capability through informal channels for technology transfer, such as OEM production arrangements, reverse engineering of imported machines, technical training as part of turnkey plant importation, and so on. To lay the initial technological foundation, many Korean industries resorted to nonmarket processes, relying on the absorptive capacity of their workers for technology acquisition. This approach enabled them to acquire technology at a lower cost and maintain independence in business operations. But this strategy came at great cost: Korea had to abandon many of the technological opportunities that foreign direct investors might have offered. In sum, Korea owes its technological development and industrialization to the development of a strong human resource base and an outward-looking development strategy. Two major lessons from the Korean experiences are that human resources are the key to S&T development and thus to economic growth, and that nothing can better motivate private businesses to invest in

technology development than market competition. (Sungchul Chung, 2007). According to John Yoon, 2017, some of South Korea's innovations are steam mop, Kimchi refrigerator, Nano 3d printing, 64mb dram, smart prosthetic skin, Samsung galaxy smartphone

With an \$800 billion-strong economy which is the Middle East's largest and 32 million inhabitants, Saudi Arabia is looking towards a bright future. An essential pillar of its vision is predicated on combining infrastructure growth with a Saudi Arabia that is a 21st century global destination for tourists and businessmen alike. Innovation in Saudi Arabia is domiciled along tourism and business. Over the past three years, Saudi Arabia has engaged in a reformist path that showcases a sea-change for its citizens, spanning from a host of social changes to the economic field. Never before has a member of the G20 initiated such a transformative programme in terms of depth, timing, breadth, and commitment. Trade and investment are key drivers of growth, innovation, and job creation.

V. FINDINGS AND DISCUSSION

Power is a concept that has various definitions and various authors over time have defined power. Various definitions were considered and analyzed in this study to understand more what power is. It was revealed that power has separated people into various classes where one appears by evidences of superiority to be higher than others and he exerts this influence on people around him. One of the most profound definitions of power was given by Weber M (1947) a renowned sociologist, philosopher and political economist and he opined that power is the probability that an individual can perpetuate his/her own will without any rebuff or resistance. Findings from the study revealed that most powerful nations of the world are majorly those from the Global North. Countries from the Global South have not shown much impetus for development generally and they are tagged developing nations. Some of their characteristics include poor development, high illiteracy, poor health condition, corruption, weakened institution and this has affected innovation in those countries. With low investment in education, the drive for various innovation in engineering has been on a slow pace even with the emergence of the fourth industrial revolution. Hence, their backseat position in terms of power and innovation. Most resources critical for innovation are gotten from countries in the Global South but years of poor leadership, weak institution, corruption etc which has made the countries poor harnessers of those resources. Findings from the study revealed that power dynamics is present in all situations and it takes different forms. It influences and shapes relationships between various persons and groups, take for instance the relationship between a professor and a student, the relationship between husband and wife, the relationship between parents and children, the relationship between a ruler and a state. The power inherent is not seen but by influence it is manifested and used to control people. It was also revealed that power can be gotten by access to some privilege, resources,



inheritance, achievements etc. Understanding power and its various dimensions is important in knowing how influence is exerted on others in some of the relationships stated above

It was also found out in the study that with the dawn of the 21st century there are various innovations and this has been more reinforced by the advent of the fourth industrial revolution. This has given more impetus to innovations in the 21st century and some of these innovations are artificial intelligence, robotics and automation, autonomous and driverless vehicles, Nano technology, additive manufacturing or 3D printing, genetic engineering, Internet of things (IoT). This study made the case for how innovation can confer power. Evidences revealed some countries that are powerful and this lend support to the crux of this study. Power was conceptualized in general parlance and the top powerful nations were considered. By virtue of these innovations in the 21st century, the United State was ranked as the most powerful country in the world and evidences of innovation in the 21st century was used to support the argument.

VI. CONTRIBUTION OF NEW KNOWLEDGE

Understanding the importance of engineering education in development is vital and this study has shed light on it using various evidences. As a result of pace of development, exposure, educational level etc., there are various advances in engineering education among various nations of the world. With these advances in engineering education, some nations have assumed position of power more than others. The various dimensions by which engineering education confers power on nations were considered in this study.

VII. CONCLUSION AND RECOMMENDATION

Engineering education has been seen as the application of scientific, economic, social and practical knowledge to invent, create, design, build, maintain, research and improve structures machines, devices, systems, materials and processes. This has been the major basis for various innovations in the world. The process of innovation has evolved over the years and the 21st century innovations were considered in this study. It was revealed that by various innovations in the 21st century, it confers power on countries of the world. The study therefore recommends that there is a need to intensify efforts on engineering education in developing countries to create more innovations in the 21st century and effort should be geared towards the use and application of these innovations.

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