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Continuous Engineering Education: Pertinent for Sustainable Development

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Abstract: Sustainable development is the principle for meeting human development, natural resources and ecosystem services upon goals while at the same time sustaining the ability of natural systems to provide that which the economy and society depend. The present unsustainable development compromises the ability of future generations to meet their needs. Global warming, destruction of the ozone shield, acidification of land and water, desertification and soil loss, deforestation and forest decline, diminishing productivity of land and waters, and extinction of species and populations, demonstrate that human demand is exceeding environmental support capacities. This system of development hinders our future survival and development. The desired scenario is a state of society where living conditions and resource use continue to meet human needs without undermining the integrity and stability of the natural system. The menace occasioned by the present practice is evident necessitating a paradigm shift towards ensuring the practice of engineering with focus on the sustainable development programmes. Broad consensus in literatures show that electricity generation, flood, erosion and destruction of aquatic life degrade and deplete the ozone layer thereby altering the temperatures of the atmosphere. This comes with dire consequences of melting the ice at the extreme regions to further flood and erode the earth. Additionally, oil exploration and gas pollute the sea, rivers and land to the exclusion of agricultural operations leading to unsustainable development. The executors of all these constructions and developmental projects are engineers and constructively, engineering practice can be sustainably done to engender sustainable development. The need now is to focus on continuous sustainable engineering education to foster sound practice leading to sustainable developments in all sectors of the economy. The purpose of the paper is to discuss the need to embrace green technology in engineering Research & Development (R&D). It emphasizes the role of engineering education in ensuring sustainability in innovation creations and practice leading to sustainable development and a green economy.
Keywords: Development, Engineering, Education, Sustainable, Green economy.

I. INTRODUCTION

Engineering has been defined as the application of scientific and mathematical principles for practical purposes such as the design, manufacture, and operation of products and processes, while accounting for constraints invoked by economics, the environment and other sociological factors (Dunmade, 2016).It is the application of science for the efficient utilization of natural resources to produce wealth; and it has also been defined as the "application of laws governing forces and materials of nature through research, design, management and construction for the benefit of mankind". (Alabe, 2008). Engineers acquire tools and practice techniques in the school and employ them to harness and convert natural resources into equitable solutions to the targeted problems. Engineering is not just about mechanizing or digitizing the world to make life less burdensome and nations more powerful. Engineering as a profession ought to improve the world for the common good. The professional education of engineers demands the acquisition of a body of specialized knowledge, problem-solving skills, and good judgment for the service of society. These domains of engineering education are aimed at forming engineers who are intellectually trained, practically adept, and ethically responsible for their work. Every professional engineer, therefore, is called on not only to achieve a certain degree of intellectual and technical mastery, but also to acquire a practical wisdom that brings together the knowledge and skills in a way that best serves a particular purpose for the good of humanity (Sheppard *et al.*, 2006).

Engineers have been highly successful in creating the complex technical systems that make modern life possible. Unfortunately, we have been less successful in anticipating and addressing the negative consequences of our creations. Creativity comes with responsibility. Engineers have devised ever more efficient ways of extracting fossil fuels from the Earth and burning them for human benefit, and so must take central responsibility for addressing the urgent problems of climate change through energy efficiency and renewable energy. Engineers have designed and built cars, roads and motorways, and so must face up to the social and

environmental problems of congestion, urban sprawl, emissions and rising fuel costs. We have built water systems that provide endless supply to homes despite fresh water being a scarce resource in many places, and now engineers must help people find ways to reduce water wastage. Engineers have created technical systems that have transformed society and the environment. Whilst we should celebrate our achievements we must also acknowledge our failures (Bell, 2013).

Knowledge is vital for any society. The wellbeing and robustness of any society is dependent on the acquired knowledge of its components. All of the divine religions attest to this universal tenet. Universities and institutes of higher learning are regarded as centers where knowledge is created, taught, and applied for the benefit of mankind. Knowledge is continuously being developed and updated so that it can enlighten and improve the lives of our global community. Universities are beacons of hope, peace, new ideas and ideals, and exemplary discipline to those who function and enroll in them. They are centers that educate and train future generations of engineers, scientists, technologists, economists, and politicians who will bear the brunt of leading and directing this world of ours into the future. The future is unknown; thus a need for well qualified, realistic, pragmatic, and above all, ethical and moral 'managers' who will make the right decisions, so that society's and indeed, mankind's aspirations, goals, and objectives will be achieved and realized. Literature and debate on sustainable development has concentrated mainly on physical and tangible issues and assets: population growth, resource depletion, environmental impact, climate change, poverty, and illiteracy. While the list is not exhaustive, many pundits have failed to realize that the most pressing ingredient and the most scarce resource facing the sustainability concept is not in the physical components of society's endowment, but rather, the ethical and moral values of 'managers' – individuals that are entrusted to plan, oversee, and implement a successful economic and social development program that will sustain mankind to live in peace, prosperity, and harmony with this universe (Al-Rawahy, 2012). Engineers are pertinent to the economic and social development of any nation as the products and processes engendered by their expertise and practice are the active elements propelling economic growth. Once the sustainability sense, culture and direction is accentuated and ethically inculcated in the professionals' engineering practice in Nigeria; problem solving would no more be achieved at the damage of the environment.

When the needs of the wider community and environment are in conflict with the requirements of employers or clients, engineers are faced with creative and ethical dilemmas. In some circumstances it may be possible to devise creative solutions that address seemingly conflicting requirements. For instance, specifying energy efficient lighting or building materials can save money for the building owner and reduce carbon emissions. In other situations, the engineer may need to bring the ethical implications of harmful systems and technologies to the attention of their client or employer. Professional engineers can raise their concerns with their employers or clients and demonstrate the value in ethical practice, they can raise concerns with external organizations such as regulators or professional associations, and they can choose to work only with ethically sound clients or organizations (Bell, 2013).

Engineers deploy resources to drive the world's economic activity, in virtually all economic sectors, e.g., industry, transportation, residential, commercial, agriculture, communication, etc. These resources, whether fuels, minerals or water, are obtained from the environment, and wastes from engineering processes (production, transport, storage, utilization) are typically released to the environment. Figure 1 depicts the environment as source for resources needed by engineering for improved standards of living; and also sink for our wastes (Dunmade, 2016).

Resources are taken from our environment for food, clothing, housing, transportation, and other necessities of life. But there is a limit to the productive capacity of the earth. Many of the resources we draw from the environment to meet the aforementioned needs are not renewable and the rate at which we harvest some of the resources is too fast to regenerate. Similarly, our engineering activities in the process of meeting the aforementioned housing, energy, transportation and other needs release enormous amount of wastes and emissions to the environment. The rate of release has been so high that it has surpassed the earth's absorptive capacity. Consequently, these voracious resource exploitation and enormous waste releases are causing resource depletion, loss of biodiversity, deforestation, desertification, global warming, ozone layer depletion, eutrophication, birth deformities, and various types of diseases; definitely, something has to be done to arrest the negative trend (Dunmade, 2016).

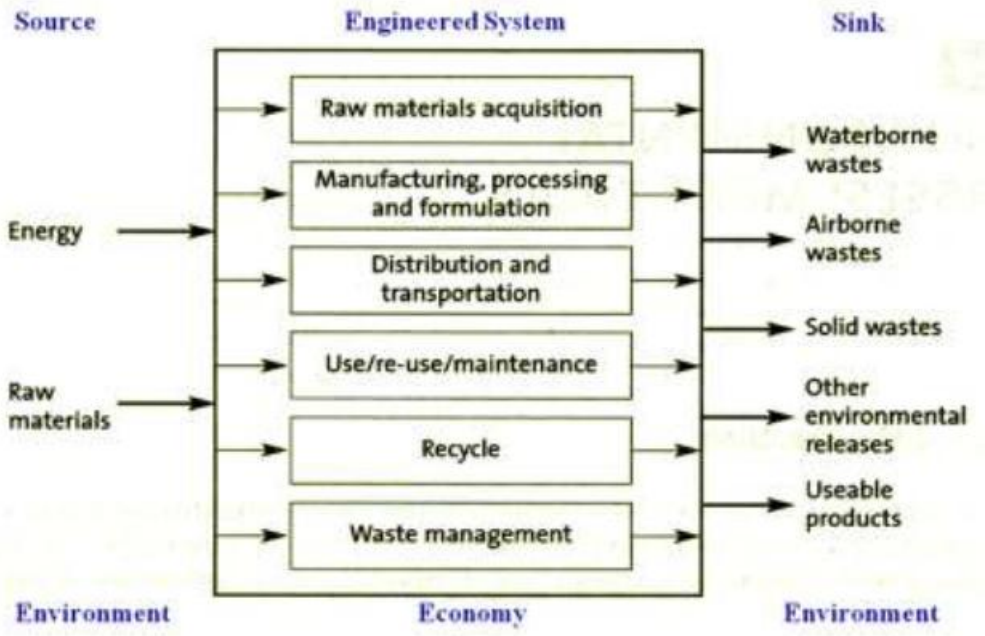

Figure 1: Engineering and our environment
(Source:Dunmade, 2016).

The world is becoming a place in which the human population is becoming more crowded, more consuming, more polluting and more connected. There is a growing recognition that humans are altering the Earth's natural systems at all scales, from local to global at an unprecedented rate. This has raised an important issue of maintaining a balance between satisfying the needs of an exponentially increasing population and preserving the carrying capacity of our ecosystems and biological and cultural diversity. A related question is what should be done now and in the near future to ensure that the basic needs for water, sanitation, nutrition, health, safety, and meaningful work are fulfilled for all humans. (Qureshi and Nawab, 2013).The opinion is that engineers who create enormous and varied technologies that impacts tremendously on the lives of the people of the world with attendant adverse effects on the environment are in the best position to effectively mitigate the misdemeanors of environmental degradation through an ethical reordering in the profession. Engineers provide the bridge between science and society. They must therefore actively promote and participate in multidisciplinary teams with other professionals, such as: ecologists, economists, medical doctors, and sociologists, to effectively address the issues and challenges of sustainable economic development because engineers working on a global scale will help promote public recognition of the profession and understanding of the needs and opportunities in today's fast developing world in order to ensure the ultimate goal of sound sustainable economic development in the country.

II. METHODOLOGY

The study involved an extensive literature review which critically analyzed the hitherto unsustainable approaches leading to the present environmental degradation and pollution emanating from products and processes generated in the course of the practice of engineering profession across the globe. The work relies on facts of action as evidenced in reports and literary items. It recommends the inclusion of the Triple Bottom Line model in the Professional Code of Ethics of all engineering related professions as well as Sustainability Engineering courses in schools curricula.

III. STATEMENT OF THE PROBLEM

Much of the present progress in development in Nigeria is at the expense of future generations. For example, irresponsible planning and environmental degradation through exploitation of resources generates waste and pollution that damages ecosystems. Engineers are key players in resource exploitation; planning and other development strategies and equipment utilized. Lagos, Kano, Port Harcourt and other cities face pressures such as waste management, transportation, urban sprawl, fresh air supply, clean water supply and access to green areas; underscoring the reality that our developmental methods and systems are not sustainable in the long term.. Thus the long term sustainability of our towns and cities is at risk. Commuting is an example. Long distance commuting by car is regarded as unsustainable because of energy consumption, traffic congestion and

deterioration in the quality of life for those concerned. This type of unsustainable development puts increasing pressure on the natural environment as building materials and energy resources are extracted from ecosystems. The challenge is to change this unsustainable pattern and create a more evenly balanced relationship with our natural environment.

Predicated on Nigeria's sole dependency on oil and its manner of exploration as engineers designed it, the scourge of environmental pollution has reached a frightening scale in recent years especially in the Niger-Delta region. The exploitation of large crude oil deposit discovered in this region has been a major contributory factor to environmental pollution in this region. (Erakhrumen, 2007). The utilization of same in commuting and energy provision further increases the pollution and environmental degradation. Evolution of sustainable practices in the exploration and utilization of our natural resources is imperative if we would cease endangering the lives of our future generations.

IV. SUSTAINABILITY

The environment does not exist as a sphere separate from human actions, ambitions, and needs and attempts to defend it in isolation from human concerns have given the very word "environment" a connotation of naivety in some political circles. The word "development" has also been narrowed by some into a very limited focus, along the lines of "what poor nations should do to become richer," and thus again is automatically dismissed by many in the international arena as being a concern of specialists, of those involved in questions of "development assistance." But the "environment" is where we live; and "development" is what we all do in attempting to improve our lot within that abode. The two are inseparable (Kates et al, 2005). Sustainability is a characteristic of a process that can be maintained at a certain level indefinitely. From an environmental stance, the term refers to potential longevity of vital human ecological support systems, such as planet's climate system, system of agriculture, industry, forestry and fisheries, and human communities in general, and the various systems on which they depend. Sustainability is an approach to decision making that considers the interconnections and impacts of economic, social and environmental factors on today's and future generations' quality of life. It is a dynamic and evolving notion, and as a process, it strives to be participatory, transparent, equitable, informed, and accountable(Qureshi and Nawab, 2013).

Overall sustainability is often considered to have three distinct components: environmental sustainability, economic sustainability and social sustainability. Overall sustainable development in general requires the simultaneous achievement of environmental, economic and social sustainability. Achieving this balance is indeed a challenging task (Rosen, 2012).Sustainable economic development is therefore the challenge of meeting human needs for natural resources, industrial products, energy, food transportation, shelter and effective waste management while conserving and protecting the environment for future human and capital development when they are fully harnessed to create jobs and generate income for the government for the purpose of economic development and transformation of society to the glory of God (Okoye, 2010). These three broad themes of social, environmental and economic accountability are collectively called the 'Triple Bottom Line concept of sustainability'. (Qureshi and Nawab, 2013). The Triple Bottom Line model depicting the constraints of sustainable development is represented in the form of a simple Venn diagram in figure 2.

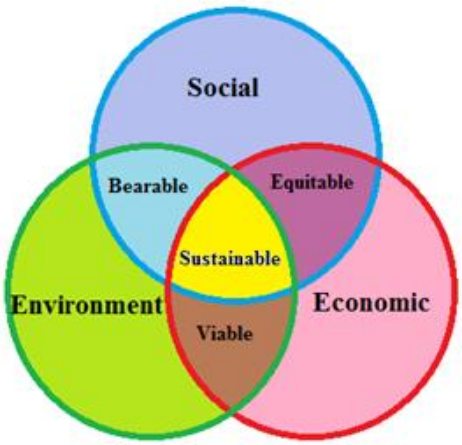

Figure 2: The triple bottom Line model
(Source: Brusseau 2019)

Sustainable development is the process of moving human activities to a pattern that can be sustained in time without end. It is a positive move towards the environmental and growth issues that seek to reconcile

human needs with the capacity of the planet to cope with the consequences of human activities. Sustainable development consists of the three broad subject matters of social, ecological and financial responsibility which is said as the Triple Bottom Line concept (Dutta and Sengupta, 2014).

Thus, Sustainable development involves the simultaneous pursuit of economic prosperity, environmental quality, and social equity. That companies aiming for sustainability need to perform not against a single, financial bottom line but against the triple bottom line. The Triple Bottom Line model concept goes beyond previous constructions of "sustainable development (SD) and corporate social responsibility (CSR) to encompass an approach that emphasizes economic prosperity, social development and environmental quality as an integrated method of doing business. This model implies a shift away from the emphasis of organizations on short-term financial goals to long-term social, environmental, and economic impacts (Amos and Uniamikogbo, 2016).

V. ENGINEERING EDUCATION AND PROFESSIONAL ETHICS

Engineering uses resources to drive much if not most of the world's economic activity, in virtually all economic sectors. Also, resources used in engineering, whether fuels, minerals or water, are obtained from the environment, and wastes from engineering processes (production, transport, storage, utilization) are typically released to the environment. Finally, the services provided by engineering allow for good living standards, and often support social stability as well as cultural and social development (Rosen, 2012). Given the intimate ties between engineering and the key components of sustainable development, it is evident that the leading participation of engineers is a critical aspect of achieving sustainable economic development.

Engineers are problem solvers. They are required and expected to make decisions that will affect their organization, themselves, and their society in terms of their wellbeing, economically or otherwise. They are required to act professionally, ethically, and maintain social responsibility in their profession and in their decisions. Engineering projects such as airport construction, petroleum and natural gas, mining, chemical and petrochemical plants, and waste facilities; all have apparent benefits and costs to society. Communities that live in close proximity to these projects may likely be affected (positively or negatively) by the proposed engineering projects. In any type of a project or product production or any venture for that matter, there are benefits and costs that can be monetary or otherwise. Environmental consideration of the project needs to be properly assessed before approval is given (Al-Rawahy, 2012).

A commonly held perception of engineering is that it is about the 'triumph of man over nature'. It is associated with the construction of massive dams for water and power supply, canals carved through the land to enable passage for trade, bridges spanning untamed waters, nuclear power plants with electricity transmission lines marching through the landscape, and sending people into space. One could be forgiven for thinking that engineering has little to do with sustainability, or even that it is aimed at achieving the opposite, and to some extent this was true in the past. However, the profession of engineering has undergone a revolution in its thinking over the last 20 or so years, and sustainability is fast becoming a cornerstone of all engineering practice (Mills *et al.*, 2011).To an engineer, a sustainable system is one that is either in equilibrium, or one that changes slowly at a tolerable rate. This concept of sustainability is best illustrated by natural ecosystems, which consist of nearly closed loops that change slowly. For example, in the food cycle of plants and animals, plants grow in the presence of sunlight, moisture and nutrients and are then consumed by insects and herbivores which, in turn, are eaten by successively larger animals. The resulting natural waste products replenish the nutrients, which allow plants to grow and the cycle to begin again. If humans are to achieve sustainable development, we will have to adopt patterns that reflect these natural processes. The roles of engineers in sustainable development can be illustrated by a closed-loop human ecosystem that mimics natural systems. This model of a closed-loop ecosystem was first proposed in 1990 (WFEO, 2002).

In many institutions engineering education is out of step with the needs of modern society, and recent reviews of engineering education have consistently called for changes to curricula. Studies portrays the traditional engineering education paradigm as 'not developing curricula that would train engineers to anticipate and focus on the rapid changes by which the 21st century will be at least partially defined. The studies posits that in order to address the complex issues of the future, modern engineers need 'a solid understanding of globalization; to understand other cultures, especially the societal elements of these cultures; to work effectively in multinational teams; to communicate effectively; to recognize and understand issues of sustainability (Mills et al., 2011).

Present day Engineers should carry on their shoulders the responsibility of endorsing the principles of sustainable growth. Sustainable development deals with meeting existing individual needs from naturally accessible reserves, while preserving and enhancing the surrounding environmental quality.Engineers are the valuable part of the society. This necessitates them to put together the determined efforts in discovering all of the relevant facts pertaining to the design, development, operation and all achievable outcome of the choices available that may positively and negatively affect the society and the public. Citizens are entirely reliant on

their premeditated products and goods that should be robust, safe, reliable, economically feasible and environmentally sustainable (Dutta and Sengupta, 2014).

Considering the problems facing our planet today and the problems expected to arise in the first half of the twenty-first century, the engineering profession must revisit its mindset and adopt a new mission statement - to contribute to the building of a more sustainable, stable, and equitable world. "Sustainable development will be impossible without the full input by the engineering profession." For that to occur, engineers must adopt a completely different attitude towards naturaland cultural systems and reconsider interactions between engineering disciplines and nontechnical fields As we enter the twenty-first century, we must embark on a worldwide transition to a more holistic approach to engineering. This will require: (1) a major paradigm shift from control of nature to participation with nature; (2) an awareness of ecosystems, ecosystems services, and the preservation and restoration of natural capital; and (3) a new mindset of the mutual enhancement of nature and humans that embraces the principles of sustainable development. The role of engineers will be critical in fulfilling those demands at various scales, ranging from remote small communities to large urban areas (megacities), mostly in the developing world (Qureshi and Nawab, 2013). If engineers are not ready to fulfill such demands, who will?

VI. CONCLUSION

Engineering accreditation as well as accreditation in related disciplines plays an important role in assuring the quality of engineering and technological education worldwide. The Nigerian Society of Engineers (NSE) and the Council for the Regulation of Engineering in Nigeria, (COREN), the National Board for Technical Education (NBTE) together with similar bodies in engineering related professions are entreated individually and collectively to ensure the inclusion of Sustainability Engineering inthe Curricula of all the fields of engineering and related disciplines. It is expected that an engineering graduate from any Nigerian University henceforth will exhibit critical awareness of the sustainability and impact of engineering activity on the social, industrial and physical environment. He should also demonstrate an understanding of the interactions that engineering has with the economic, social, health, safety, legal, and cultural aspects of society, the uncertainties in the prediction of such interaction. The time to enforce this conditionality is now.

For Professional Engineers and other related disciplines already in practice, the relevant practice controlling and regulatory agencies should enforce the Triple Bottom Line model in their Code of Ethics. Code of Ethics is a guide of principles designed to help professionals conduct business honestly and with integrity. A code of ethics document may outline the mission and values of the business or organization, how professionals are supposed to approach problems, the ethical principles based on the organization's core values, and the standards to which the professional is held.A code of ethics is important because it clearly lays out the rules for behavior and provides the groundwork for a preemptive warning.

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