Prospective Inclination of Research and Engineering Education

Emmanuel Emem-Obong Agbenyeku, Edison Muzenda and Innocent Mandla Msibi

Abstract**—**The roles of Engineers are generally vital as their knowledge and expertise play a pivotal part in societal improvement, offer empowering ideas, innovations and initiatives that motivate financial and economic progress, enrich social and physical infrastructures, and also stimulate transformations that advance quality and standard of living. Concurrently, there are enormous challenges weighing on all facets of research and development (R&D), industry and manufacturing owing to globalization and circulated manufacturing. On this note, the corporate and commercial setting of manufacturing enterprises are categorized by incessant modification and growing intricacies. Most companies are in dire need of dynamic technical solutions as well as handling composite socio-technical systems geared towards substantially contributing to the sustainable growth and development of manufacturing and the environment. For this reason, in the ever changing industrial and business world of Engineering, Health delivery, Environment, Transportation, Logistics and Supply chain amongst others, researchers and graduates are profusely required once they display the ability to comprehend both composite technological processes and the resourceful arts and social skills. Thus, through the proficient technical and communication skills of engineering managers, various team-based activities are successfully supervised and executed. As such, aiming at the crucial role of engineering in solving simple to compound global problems make the career attractive to all gender of students.

Keywords**—**Sustainability, Engineering Education, Socio-technical systems, Researchers, Engineers

I. INTRODUCTION

IT is very pertinent to note and admit that the global issues weighing on the diverse aspects of life today requires an even more diverse and composite framework of society, environment, economy and technology to resolve them. The chatter for sustainable growth, development, implementation and enforcement have been in the frontlines of events in almost every facet of industrial, sectorial and global pursuits in present times. More to this, economical sustainable production/manufacturing, high added value and knowledge-base are generally seen as basic drivers of industrialization diversification. It is generally known that engineering design and push-out production as well as the broader scope of engineering impacts fundamentally all areas of society. This implies that a large portion of the population are considerably involved executing the plans and designs of engineers. However, with all of these insistent global changes and challenges, one question is often asked by the general public: what then is the task of engineering in addressing and resolving the needs of society? As reported by [1] this question is persistently being asked with a greater tone of firmness by societies, considering what they have profited from massive improvements in technology, and on the other hand, all they have lost and experienced by technological association and involvement.

Nevertheless, it must be emphasized that the debates and questions about technology are often mixed up with questions about engineering. Regardless of the increasing database and literature on the respective connection of technology and engineering to the society, the mind of the public still perceives it differently. As earlier stated, the downsides, impacts and side effects of technology have come a long way yet continues to increase as it concurrently adds to the doubt of societies. In light of the fact that it may be inappropriate to fault the engineer for the seeming lack of interest by the broader society in understanding the technological process with all its limitations and prospects, it is however, expected that engineers can possibly do more to lessen societal doubts by way of open mindedness and active involvement. As recorded by [1] the National Academy of Engineering announced the following "Engineering Grand Challenges" to include the following:

i. Make Solar Energy Economical;
ii. Provide Energy from Fusion;
iii. Develop Carbon Sequestration Methods;
iv. Manage the Nitrogen Cycle;
v. Provide Access to Clean Water;
vi. Engineer Better Medicines;
vii. Advance Health Informatics;
viii. Secure Cyberspace;
ix. Prevent Nuclear Terror;
x. Restore and Improve Urban Infrastructure;
xi. Reverse Engineer the Brain; Enhance Virtual Reality;

Manuscript received March 0, 2016; revised March 0, 2016; submitted for review April 15, 2016.

Emmanuel Emem-Obong Agbenyeku is a research student at the University of Johannesburg, South Africa (phone: +27 11 559 6396; e-mail: kobitha2003@yahoo.com; emmaa@uj.ac.za).

Edison Muzenda is a Professor of Chemical and Petroleum Engineering and Head of Department of Chemical, Materials and Metallurgical Engineering, College of Engineering and Technology, Botswana International University of Science and Technology, Private Mail Bag 16, Palapye, Botswana, as well as visiting Professor at the University of Johannesburg, Department of Chemical Engineering, Faculty of Engineering and the Built Environment, Johannesburg, P.O.Box 17011, 2028, South Africa (phone: +27 11 559 6817; e-mail: emuzenda@uj.ac.za; muzendae@biust.ac.bw).

Innocent Mandla Msibi is Group Executive of Innovation and Impact, Water Research Commission, Pretoria; Research and Innovation Division, University of Johannesburg, South Africa (phone: +27 12 330 0344; e-mail: mandlam@wrc.org.za).

xii. Advance Personalized Learning; and

xiii. Engineer the Tools of Scientific Discovery.

Human survival and existence relies strongly on some of the mentioned challenges as some will guard against human and natural threats but ultimately all of the listed challenges are targeted at advancing the quality and standard of living. An observation by [1] stated that all the listed challenges are multifaceted issues of global measures that also coincide as socio-technical composite structures.

II. PUBLIC PERCEPTION OF ENGINEERING

Generally, engineers in/ by training as well as a large portion of society regard engineering as a mere form of applied science. Contrary to the general perception, engineering entails more as it is an integral part of society. As such, an education that highlights engineering and society, or better still, "Engineering Arts", as against the known conventional and traditional Engineering Science is what is required towards a paradigm shift. The functionality and sole existence of engineering is intertwined with society and as such one cannot be independent of the other as each is a required portion to feature and operate within reality. Hence, a better comprehension of what necessities and constrictions are laid on engineers by the rest of society including what role the engineer realistically can or should play in that society requires dire attention.

A. Socio-Technical Structures

The nexus between engineering and society is multifaceted gearing towards the core of impracticable expectations over conventional and traditional engineering, as on the one hand, social units are becoming more inefficiently organized to advance and utilize engineering effectually. While on the other hand, engineers unable to take their abilities and transform them to solutions of social/ societal problems or channel them towards the operative organization of the engineering enterprise are fast becoming frustrated. However, engineers should find the socio-technical structure an agreeable and more realistic leeway. This is because as engineers, and particularly field and production engineers for that matter, have to engage in active systems i.e., technical systems all the time and become conversant with how to design, analyze and oversee/ manage the process. In the case of the socio-technical model, the entire society is envisaged as an enormous unified system, having diverse social and technical areas of human activity as major networking subsystems. Engineering in this context feature as one of the subsystems. Hence, to examine the subsystems they must be split into sub-subsystems and sub-modules, components and even items; which are then analyzed independently with a view to recoupling the whole system. The idea of engineering as an adaptive socio-technical subsystem functioning within the adaptive socio-technical structure of society offers an even greater compound model to instrument. This comes closer to reality, although, than the model of engineering and society as different and discrete units.

B. Need for Socio-Technical Structures

In present times, it is more or less a cliché to express how any single technology can be utilized in multiple ways and applied to various unanticipated conducts. However, it is pertinent to note that, for every distinct application, the technology is imprinted onto a multifaceted set of new/ other technologies, procedures, people, physical surroundings etc., that collectively compose of the socio-technical structure. Therefore, only when this structure is understood can it be used to analyze the societal, ethical and environmental challenges and effects. More so, numerous ethical challenges are closely connected to the social/ societal and environmental structures. As such, they are socio-technical systems and the ethical challenges connected to them are founded in the actual combination of technology and social structure. Furthermore, it is the technology entrenched in the social systems that forms the ethical challenges. The major task/ dilemma presently is finding an equilibrium between the rights and freedoms of individual’ and that of society.

C. Socio-Technical Structures and Inclinations

Social changes have over time evolved with evolving technologies. This includes the industrial transformation/ industrialization triggered by technology, together with the expansion and extension of cities and suburbs caused by the automobiles. In today’s day and age, the computer-inspired century of information technology and wireless communication systems have transformed entirely everything around the globe. As such, through technology the truism about the world being a global village has been drawn closer to reality. As time continuous to progress, man and machine increasingly interact as the dependency on computer systems, information systems, social media systems and communication systems, on and off-line information systems, system weaponry etc., are insistently increasing and constantly being adapted and used in everyday life. Mass production of standardized goods born out of industrialization, caused to a great extent the limitation and/ or deprivation of freedom of choice of consumers.

The present jet age has allowed computers the potential to provide individuality, through flexible, reconfigurable computerized manufacturing that permit vast ranges of individualized products. Nevertheless, one essential remain of the jet age is the increase in complexity which includes; technological systems, business systems, and social systems complexities. These composites appear to illustrate a form of the second law of thermodynamics- Entropy, which is insistently increasing. This phenomenon is particularly displayed in large-scale systems such as global distributed manufacturing, transportation, the environment and the earth's ecosystem, as well as in the strategic defense and security systems. One vital question of whether the ability of computers to manage complexity and information, and decision systems can keep up with the persistent rise in complexity is forever on the lips of the general public and society. However, there seem to significant hope due to the influence of modelling, simulation and availability of supercomputers which may be deployed and harnessed to address socio-technical problems thereby, allowing a new and better understanding as well as offer the ability to deal with societal problems. Considering that the social and business systems have also been adapting to the information age, intellectual property has become a vital aspect of law which has added its own complexities to an increasingly divisive society. The financial system has new problems of stability and control, as exemplified by program trading and the increasing volatility of the market. More to this, the recent savings and loan crisis has shown the vulnerability of the banking system. The time constraints and turbulence in the economic system have also worked against the development of new science and technology, as business leaders are more engrossed in short-term profitability rather than the long-term investment required for stable research.

III. ENGINEERING EDUCATION AND SOCIETY

Understanding how engineering reacts to the needs of society requires critical assessment of its social and functional systems. For instance, most people who study engineering in North America have skills in higher physics, biology and mathematics while some have communication and social proficiencies. This seems to reduce their chances and involvement in politics as well as their success in communicating with the rest of society. In turn, an engineer is often seen by society as a narrow, conservative, numbers-driven person, unresponsive to subtle societal issues. The methodical study of socio-technical problems rarely features in engineering curricula as an important sphere of engineering activity. The curricula usually focus on man-made artifacts to the exclusion, except for specialized cases at the graduate studies level. This narrow focus has swayed engineering from not only a rich source of inspiration for specific technical achievements and knowledge obtainable by systems of great delicacy and complexity, but also a deeper understanding of environmental change.

According to [1] most high school students today do not view an engineering education as a path to success and prestige worthy of the sacrifices of a rigorous curriculum. Even bright young engineering students, upon graduation, switch to careers in business management, law, and medicine. Also, engineering continues to be a powerful tool for social mobility and advancement for immigrants and the poor. However, it is well recognized by most governments that in order for a country to prosper and compete globally, more engineering and science graduates are needed as they contribute immensely to a nation's wealth, growth and development. In various societies engineering offers most of the same outcome including; shelter, energy and communications, manufacturing, water supply, extraction and use of resources, and disposal of waste. There are societies however, where engineers carry out broader functions by virtue of the position they hold. In several European and developing countries, engineers head state organizations and major industry corporations, participate in government, and enjoy high social prestige. Although, in other parts of the globe like in most developing countries in Africa, engineers are absent from major positions of societal leadership, and only a handful serve in government, in Congress, in Parliaments, or at the cabinet level. The profession is, in a sense, handicapped in terms of serving society in a broader spectrum by a pecking order that prizes activities connected with the design of tangible products above the challenges of manufacturing, operations, and maintenance, or public service at large.

A. Social Requirements and Obligation

Manufactured products have generally advanced through the gradual process that has shaped man and other biological species. As such, there is a constant question of whether the technology being developed enhances the long-range survival of our species. It should however be noted that there is increasing body of research that use biological evolution as a metaphor for developing products and systems as recorded by [2]. An important determinant of how well engineering satisfies its social purpose is the breadth of engineering. Engineering in present time proceeds significantly to center on inanimate products or machines, as engineering school curricula worldwide continue to bypass socio-technology. The factory environment single-mindedly rationalized by the engineer F. W. Taylor discounted the effective integration of the worker, biological unit and the machine in the manufacturing/ production process. This is basically the case in virtually everywhere in the world, with Japan being in exclusion where a different social attitude created a more effective incorporation with humans, as well as the artificial version, known as artificial intelligence or intelligent robots. Another reason for the difficulty engineers encounter in dealing with social issues has to do with the various, and often conflicting, needs of social groups (educational, economic, environmental, health, public service, spiritual, and government) that engineering and technology may be expected to satisfy.

The recurrent conflict between advocates of independent and targeted research is an example and an inevitable result of the tension between short-and long-range needs. Nevertheless, such conflicts may cross the boundary between what is socially useful and what is out of control. Most governments in the developed world that fund research, including in developing Africa particularly South Africa, are at the edge with regards to this issue. A balance must be struck between short- and long-term needs. These projections both serve a useful purpose because it is impossible to have a strategy void of implementation and application. Equally, operating without a long term research base plan can have catastrophic impacts over time. For example, the health care system in most developed and developing countries, has increasingly engrossed a larger quota of gross national product, irrespective of the condition of economic prosperity. Also, it has continually become highly priced and more difficult to access to larger populace. More to the issues, the challenges of hunger, drought, poor crop yields etc., remains endemic in many parts of the globe regardless of advances in agricultural technology. In fact, where yield and production is high in some countries, produce and supplies are lost for lack of effective storage and distribution systems. At this juncture, the argument that engineers need to check their cultural responsibility and involvement to society as they contribute to transformation can be tabled. Therefore, as recorded by [3] effort must be initiated at university level and from professional societies towards educating prospective engineers as well as researchers. The following five guiding principles with some already rooted in the conscience of engineers were posited by [4]:

i. *Uphold the dignity of man*: - this is an essential value of our society that should never be violated by an engineering design. This could happen when the design or operation of a technological product fails to recognize the importance of individuality, privacy, diversity and aesthetics.

ii. *Avoid dangerous or uncontrolled side effects and by-products:* - this demands a rigorous development of a design or a technology considering all the functional requirements and constraints whether social, political, economic, popular, or intrinsically technological.

iii. *Make provisions for consequence when technology fails*: - the importance of making provisions for the consequences of failure is self-evident, especially in those systems that are complex, pervasive, and put lives at risk upon failure.

iv. *Avoid supporting social systems that perform poorly and should be replaced*: - this runs much against the grain of most engineers. Short-run technological fixes can put lives at risk in the long-term. In the case of energy, for instance, technological or commercial fixes cannot mask the need to rethink globally the impact of consumerism and the interrelationship of energy, environment, and economic development.

v. *Participate in formulating the "why" of technology*: - *a*t present the engineering profession is poorly equipped to do so in South Africa and other countries around the globe. Few engineers, for instance, have been involved in developing a philosophy of technology. This separation of engineering and philosophy affects our entire society. Engineers, in shaping our future, need to be guided by a clearer sense of the meaning and evolutionary role of technology.

The great social challenges facing virtually the whole world today requires rethinking of the human-artifact-society interrelationship and the options it offers us to carry out a growing number of social functions using quasi-intelligent products to instruct, manufacture, inspect, control, and so on.

IV. PROSPECTIVE RESEARCH AND ENGINEERING

Present generation of students are better inclined with global issues and the need for new approaches than their predecessors. For this reason [3] discussed the future of engineering in detail. By focusing on the critical role of engineering in solving the most complex global issues, aspirations to make the profession more attractive to both male and female students, especially the latter is ensured. The new definition of engineering/ engineers according to [5] defined it as: "The enablers of dreams". Engineers play a vital role in societal development, contributing to and enabling initiatives that drive economic progress, enhance social and physical infrastructures, and inspire the changes that improve quality of life. Engineers are committed to helping provide the best possible quality and standard of living for all of society. Therefore, the aspiration that engineers will continue to be leaders in the drive for the use of wise, informed, economical and greener approaches towards sustainable growth and development in all facets of societal needs is very pertinent. However, this should commence from the grass root of educational institutions and be founded in the basic principles of the engineering profession and its actions. The objective for a future where engineers are prepared to adapt to changes in global forces and inclinations and to ethically assist the world in creating a balance in standard of living for developing and developed countries alike is paramount to paving way for a sustainable future.

The following resolve should therefore be targeted towards bettering the prosperity of societies going forward:

I. Deliver engineering innovation domestically and to the global community

II. Deliver specific engineering capabilities that will be needed in the future to improve health and safety, provide for a cleaner environment, and enable more sustainable development

III. Address areas in which advocacy by the engineering profession can lead to public policy development and directly contribute to an standard and quality of life

IV. Make educational improvements that will foster broader involvement in the profession by all segments of society and nurture innovation.

Also at a higher level, it must be acknowledged and ensured that the following are pursued going forward:

a. A larger collaboration across disciplines and professions
b. An increase engineers' influence and involvement in policy making
c. A re-assessment of accreditation processes
d. A transformation in engineering education and practice
e. An encouraged participation of all groups and peoples
f. An attractive and retaining environment especially for women in larger numbers.

Attention to sustainability and globalization issues should therefore be propagated towards educational objectives and key prospective inclinations that will aid redefine the future and interaction between engineering and society through the following:

- Challenges in developing secure and sustainable forms of resources, including energy and water
- The need to develop more sustainable practices in all branches of engineering
- Increased opportunities for technology to improve human health
- Globalization and its impact on industrial supply chains, education, research and the human condition

Furthermore, the Guiding Principles and Core Professional values of Engineering should include:

1. An innovative and stimulating learning environment where students can prepare themselves to excel in life
2. To achieve the next level in research outcomes and reputation by building on existing and emerging areas of excellence
3. To build an all-inclusive society with related and shared purpose
4. To be honest, mutually respectful, fair and involved
5. To foster a collegial, interdisciplinary and innovative work environment
6. To respect and reflect diversity in opinions, recruitments and the society under construction
7. To engaged in engineering according to the highest standards of professionalism
8. To act ethically and with integrity
9. To expect the best out of students and nothing less
10. To instill in students the desire to learn

11. To inspire students to see themselves as global engineers
12. To be stewards of the environment and execute social responsibility in research and education.

V. CONCLUSIONS

This paper was a medium to explore the nexus between engineering and education as well as other disciplines. The paper pushed to emphasize the stretch of engineering across and in connection to various subject areas including technology, inclined to the challenges facing society. The basic point here from is to encourage a leading integrated, interdisciplinary undergraduate engineering education for all engineering students, with great specificity to females. Such that, students interested in an educational experience that offers a rich mixture which balances technical matters/ subjects can possess a deeper sense and understanding of the role of an engineer in addressing sustainability and the challenges, and key socio-technical issues affecting our immediate society and the global hub at large.

ACKNOWLEDGMENT

The Authors appreciate the University of Johannesburg where the paper was done.

REFERENCES

[1] El Maraghy W.H. 2011. Future Trends in Engineering Education and Research. Advances in Sustainable Manufacturing: Proceeding of the 8th Global Conference on Sustainable Manufacturing, DOI 10.1007/978-3-642-20183-7_2. Pg 11-16.

[2] El Maraghy W.H. 2008. “Changing and Evolving Products and Systems-Models and Enablers”, Changeable and Reconfigurable Manufacturing System, Springer-Verlag Publishers, ISBN: 978-1

[3] Duderstadt J.J 2008. Engineering for Changing World: A Roadmap to the Future of Engineering Practice, Research, and Education. The Millennium Project, The University of Michigan; 131 pgs.

[4] Bugliarello G. 1991. “The Social Function of Engineering”, in Engineering as a Social Enterprise (Washington: National Academy Press, 1991) 73-88.

[5] Engineers Canada; May 2009a. “Leading a Canadian Future: The New Engineer in Society”; A declaration by Canada’s engineering profession: The Montreal Declaration Issued at the National Engineering Summit, May 21, Montreal Quebec.