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Premiums of Professional Registration in Engineering Practice for Technological Advancement

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Abstract **Review Article**

This paper makes an overview of the numerous dividends and premiums derived from engineering as a profession practiced by engineering professionals producing innovations and technological advancements. Engineering provides solutions to the needs of the society and nature through scientific theories, mathematics and technological tools. Having a basic university degree in Engineering is not enough to make an Engineer a professional. The engineering profession, as with other professions, is a vocation or occupation based upon specialized education and training, as providers of professional advice and services under a professional body governed with ethics, codes and standards. Professional engineering is extending the physical and economic capacity of the society by enhancing the reach of society's components and capabilities of its members, and by creating new methods and instruments for agriculture, the production of goods, communication, defence, offence, exploration of space and the oceans, and of the preservation and utilization of nature's resources from land to energy, water and materials. Technological innovation is not complete without engineering knowledge of mathematics and science. Solutions of societal problems require that these technologies be applied in innovative ways with consideration of cultural differences, historical perspective, economic constraints and others.

Keywords: Engineering, Profession, Technology, Science, Society, Innovations.

INTRODUCTION

While meanings do change, the concept of engineering derives from the dawn of human history as our ancestors developed and designed tools that were essential for their survival. Engineering is the field or discipline, practice, profession, and art that relates to the development, acquisition and application of technical, scientific, and mathematical knowledge about the understanding, design, development, invention, innovation, and use of materials, machines, structures, systems, and processes for specific purposes [1]. The term 'engineering' derives from the word 'engineer' used in the 1300s for a person who operated a military engine or machine – such as a catapult, or later, a canon. The word 'engine' in turn derives from the Latin word *ingenium* for ingenuity or cleverness and invention. The terms 'art' and 'technical' are important because engineering also arranges elements in a way that may, or may not, appeal to human sense or emotions, and relates also to the Greek word *technikos* relating to arts, craft, skill, and practical knowledge and language regarding a mechanical or scientific subject.

Engineering also connects to the natural sciences, and to the social and human sciences. Science from the Latin word *Scientia* which stands for knowledge, relates broadly to a systematic approach to the observation of phenomena and development of hypothesis, experimental and theory regarding these phenomena, and the production of knowledge upon which predictions or predictable outcome may be based. Science and engineering are essentially part of the same spectrum of activity and need to be recognized as such. Engineers use both scientific knowledge and mathematics on the one hand to create technologies and infrastructure in the other hand to address human, social, and economic issues, and challenges. Engineers connect social needs with innovation and commercial applications. The relationship among science, technology and engineering can be roughly described as shown in Figure-1.

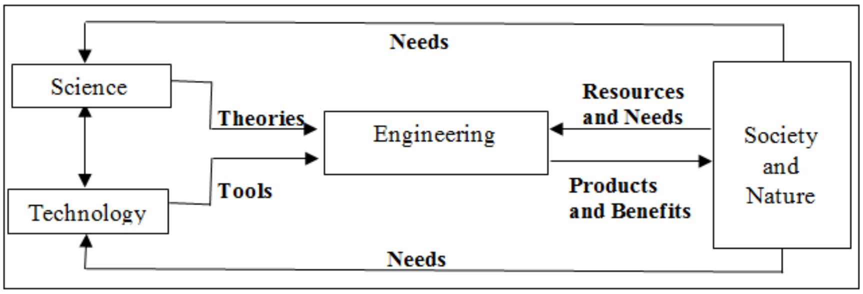

Fig-1: The Relationship among Science, Technology and Engineering [1]

People who are qualified in or practice engineering are described as engineers, and may be licensed and formally designated as professional, chartered or incorporated engineers. The broad discipline of engineering includes a range of specialized disciplines or fields of application and particular areas of technology. Engineering itself is also differentiated into engineering science and different areas of professional practice and levels of activities. The engineering profession, as with other professions, is a vocation or occupation based upon specialized education and training, as providers of professional advice and services [2]. Apart from a degree or related qualification in one of the engineering disciplines and associated skill sets, which includes design and drawing skills, engineering education also seeks to develop a logical, practical, problem solving methodology and approach that includes soft social as well and technical skills. These include motivation, the ability to perform, rapid understanding, communication and leadership under pressure, and social-technical skills in training and mentoring [1].

THE PROFESSIONALS: Engineers, Technologists, and Craftsmen (technicians)

Engineering encompasses a vast diversity of fields and levels of engineer. This is from engineers in universities who are more concerned with research and teaching what is sometimes described as the 'engineering sciences' (rather than engineering practices), to those practicing, professional, and consulting engineers, to engineering technologists and craftsmen (technicians). As engineering changes, so does the idea and definition of what it means to be an engineer [3]. Engineering qualifications and professional registration with regulatory bodies (COREN in the case of Nigeria) may in many countries be categorized as falling into one of the three generic tracks, namely: Engineer, Engineering Technologists, and Engineering Craftsmen (Technicians). There are a number of approaches to the regulation of a profession around the world. Broadly distinguished as [4];

1. ***Licensing***: in this approach, and area of engineering work is linked to those persons who have demonstrated competence to perform such work. Licensing on a statutory basis prohibits unlicensed persons from performing such work. Non-statutory licensing provides the public with lists of persons competent to perform work within an area of engineering, which may also be undertaken by non-licensed persons.
2. ***Registration:*** in this approach, those persons who demonstrate their competence against a standard and undertake to abide by a code of conduct, are awarded titles and are admitted to a register. Such registration may be governed by the laws of a country (statutory register) or the regulations or the rules set by the governing body of the profession, which oversees the registration process and maintains the register (non-statutory register). Where governing bodies operate non-statutory registration, they may only use civil action to prevent non-registrants from using the title and are not empowered to restrict any area of work to registrants.
3. ***Specialist lists:*** in this approach, a professional or trade body administers a non-statutory voluntary listing of professionals who have met a defined standard of competence in a specific area.

All these forms of regulation are linked to codes of conduct. Serious breaches of a code of conduct can lead to the withdrawal of a license, the loss of title, or the removal of the transgressor's name from a specific list, either on a temporary or permanent basis.

Engineers' Professional Code of Conduct and Ethics

Engineering is an important and learned profession. As members of this profession, engineers are expected to exhibit the highest standards of honesty and integrity. Engineering has a direct and vital impact on the quality of life for all people. Accordingly, the services provided by engineers require honesty, impartiality, fairness, and equity, and must be dedicated to the protection of the public health, safety, and welfare. Engineers must perform under a standard of professional behaviour that requires adherence to the highest principle of ethical conduct [5].

Rules of practice

- Engineers shall hold paramount the safety, health, and welfare of the public.
- Engineers shall perform services only in the area of their competence
- Engineers shall issue public statements only in an objective and truthful manner.

- Engineers shall act for each employer or client as faithful agent or trustees.
- Engineers shall avoid deceptive acts.

Professional Obligations

- Engineers shall be guided in all their relations by the highest standard of honesty and integrity.
- Engineers shall be at all times strive to serve the public interest.
- Engineers shall avoid all conduct or practice that deceives the public
- Engineers shall not disclose, without consent, confidential information concerning the business affair or technical processes of any present or former client or employer, or public body on which they serve.
- Engineers shall not be influenced in their professional duties by conflicting interests.
- Engineers shall not attempt to obtain employment or advancement or professional engagements by untruthfully criticizing other engineers, or by improper or questionable methods.
- Engineers shall not attempt to injure, maliciously or falsely, directly or indirectly, the professional reputation, prospects, practice, or employment of other engineers. Engineers who believe others are guilty of unethical or illegal practice shall present such information to the proper authority for action.
- Engineers shall accept personal responsibility for their professional activities, provided, however, that engineers may seek indemnification for services arising from their practice for other than gross negligence, where the engineer's interests cannot otherwise be protected.
- Engineers shall give credit for engineering work to those to whom credit is due, and will recognize the proprietary interest of others.

Professional Responsibility of Engineering in Society

From the earliest times of human civilization, the activity that has come to be called engineering has impacted on society through the technological artefacts-both tangible and intangible that it creates. Products of engineering surround us and affect virtually every aspect of our lives, influencing culture, art, and religion in a tightening circle of reciprocal interactions [6]. Every major engineering innovation, from metal-making to electronics, has brought about changes in the society. The development and practice of engineering is affected, in turn, by significant changes in society's goals, customs, and expectations. To respond to society's demands, the very education of engineers is becoming interdisciplinary, including courses in the humanities, the social sciences and biology. Societal entities that respond faster and more intelligently to engineering innovations usually have the advantage. The American and French revolutions eventually enhanced technological development by opening up their societies to the opportunities offered by the Industrial Revolution. Likewise, the Russian Revolution greatly accelerated the pace of industrialization in that country.

One of the first sources of confusion, particularly among those who are not engineers or scientists, is the distinction between science and engineering [7]. The primary role of science is to develop knowledge and understanding of the physical universe [8]. According to Davis [7], an important distinction is that this pursuit of knowledge (science) may occur largely without regard to societal needs. The direction of scientific research has been described by some as curiosity-based research which is not necessarily driven by the values of the society. The Venn diagram of Figure-2 according to Nichols and Weldon [9] that it is the overlap of scientific knowledge with societal need, more specifically, the application of scientific knowledge to the needs of the society, which is the domain of engineering.

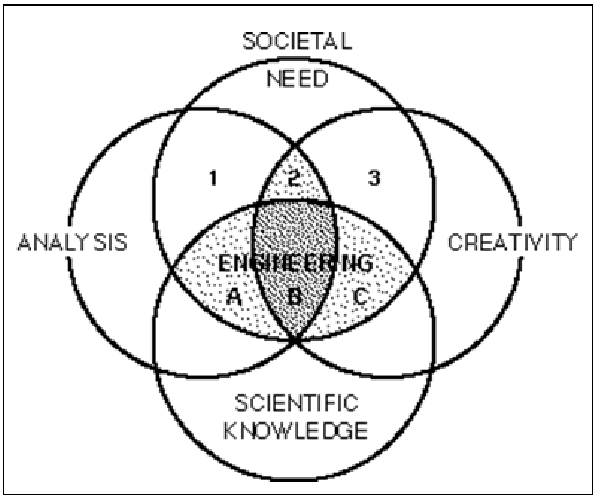

Fig-2: Interception of Scientific Knowledge with Social need: Domain of Engineering [9]

Considering the intersection of scientific knowledge with societal need (designated as the domain of engineering), Nichols and Weldon [9] discussed the three sectors, shown as A, B, and C.

Sector A: represents the intersection of purely analytical talents with the engineering domain. This may be used to represent engineering science, an ability to model complex systems and predict their response to various inputs under various conditions. This segment of engineering has, of course, been the subject of intense development over the last half century and has benefitted most directly from the availability of fast digital computers.

Sector C: the intersection of our creative capacity with the engineering domain, can be viewed as representing those sudden intuitive leaps often responsible for revolutionary advances in technology called "significant novelty" by Spier [8] as well as those aspects of engineering, not yet fully supported by engineering science, that remain more art than science.

Sector B: (the intersection of knowledge and need with both creative and analytical capability) can be used to represent engineering design and much "real world" problem solving. This sector includes activities ranging from developing innovative products and processes, to creating an innovative bridge design, to developing a new control process for petrochemical production. This vision of engineering design as the quadrilateral intersection represented by Section B is consistent with statements expressed by Pahl and Beitz [10], Dixon [11], and Penny [12].

This four-circle representation of human endeavor (Figure-2) also offers a useful perspective for other enterprises. Sector 1, the intersection of analytical skills with societal needs outside the bounds of scientific knowledge might include economics and philosophy while sector 3 may encompass the arts. Sector 2 may be used to represent those societal needs outside the bounds of scientific knowledge that required both analytical and creative skills, perhaps including public policy, business administration, and music.

Engineering Profession and Technological Advancement

Roads, aqueducts, pumps and canals have made urban life possible, electricity has illuminated and helped power the world, industries and communications have fostered global affluence and weapons of increasing power are shaping the interactions among nations. Modern music, paintings, and architecture, automobiles and modern bridges embody both art and technique as did the pyramids and the Parthenon. The fact remains that engineering and technology are processes that require the synergy of individuals, machines (artefacts) and social organizations [13]. An important facet of that synergy is the ever-closer interaction with science. The synergy of engineering with other societal activities is the root cause of the material prosperity of many societies and is a key to improving the condition of many developing countries. The rapidly developing interaction of engineering with biological and medical system is beginning to dramatically increase the health of vast sectors of the world population, and the synergy of engineering and education through advances in information and telecommunications technology, to improve skills, and job opportunities globally.

At the same time, however, developments in mechanization and automation may tend to diminish both employment opportunities and person-to-person, face-to-face interactions by interposing machines. Also as dependency on technology grows, and as technology becomes less well understood and operated to its maximum capacity – society is placed at increasing risk by technological failures and design faults, whether of logical supply systems for water, food, energy, and vaccine, or of other critical infrastructures and systems. This risk is aggravated by the ever greater interdependencies of our engineering world. Engineering in its entirety is in effect, a social enterprise that has made modern society possible, with all its potentials and risks, and is nurtured in turn by the society [14].

Professional engineering is extending the physical and economic capacity of the society by enhancing the reach of society's components and capabilities of its members, and by creating new methods and instruments for agriculture, the production of goods, communication, defence, offence, exploration of space and the oceans, and of the preservation and utilization of nature's resources from land to energy, water and materials. Engineering's evolving and depending interaction with the other components of the society and its increasing ability to intervene in biological processes have become a key factor in determining the future of our species.

Further Emphases on Engineering Technological Breakthrough

Biotechnology

Exciting breakthroughs in our understanding of human physiology have been among the most captivating topics of public discussion over the past several decades. It is the potential to attack diseases and disorders at the cell and DNA levels that leads some to believe that diseases, as currently known, may be eradicated and that compensations for many of the limitations of the human body (e.g., those related to aging or hormonal changes) will be available.

Advances in biotechnology have already significantly improved the quality of our lives, but even more dramatic breakthroughs are likely. Research in tissue engineering and regenerative medicine may lead to new technology that will allow our bodies to replace injured or diseased parts without invasive surgery, but rather by using the natural growth processes inherent in cells. Already used extensively to help burn victims grow replacement skin, it is possible that related developments will allow spinal cord injury victims to restore full mobility and feeling by reconnecting tissues and nerves.

Linked with new developments in nanotechnology and microelectronic mechanical systems (MEMS), we may see the use of nanoscale robots, or nanobots, to repair tissue tears or clean clogged arteries. Nanobots might be used to target drugs that can destroy cancers or change cell structures to combat genetically inherited diseases. Bioinformatics will likely take advantage of improved computing capabilities that use the human genome database to allow drugs to be customized for each individual. A drug that might be fatal for one person could be well suited for curing another's disease, depending on their specific genetic makeup.

The intersection of medical knowledge and engineering has spawned new biomedical engineering research and curricula that have helped create or refine products such as pacemakers, artificial organs, prosthetic devices, laser eye surgery, an array of sophisticated imaging systems, and fiber-optic-assisted noninvasive surgical techniques. In the future, ongoing developments will expand beyond the application of medical advances toward tighter connections between technology and the human experience. For example, embedded devices that aid communication or devices that monitor organ functions and provide meaningful information to the user will be available. New-century products will also be exquisitely tailored to match the physical dimensions and capabilities of the user. Bio-inspired computer researchers are already investigating virus protection architectures that mimic the human viral defense system, and pattern recognition researchers are developing algorithms that mimic the visioning processes observed in humans and other species [15].

The Information Explosion

Surrounding all these technologies is the growth of data and knowledge at an exponential rate. A few hundred years ago it was conceivable for a person to be conversant about much of the science, mathematics, medicine, music, and art of the day. Today, in an age of specialization, an individual's area of expertise continues to diminish in relation to the total body of technical knowledge. The health care field offers a daunting example of the future; there will be more new knowledge created in the next few years than in all previous history. Beginning in the early 1990s, data management requirements in life sciences-based engineering activities began to outpace Moore's law (Figure-3). These data will drive and be driven by the biotechnology revolution. Memory access rates and manipulation of databases will represent an ongoing challenge to efficiently and effectively mine these data.

In the past, engineering responded to the explosion in knowledge by continually developing and spawning new areas of focus in the various engineering disciplines. As more of these areas arise, the depth of individual knowledge increases, but the breadth can dramatically decrease. This poses a challenge to an engineering future where interdisciplinarity will likely be critical to the solution of complex problems.

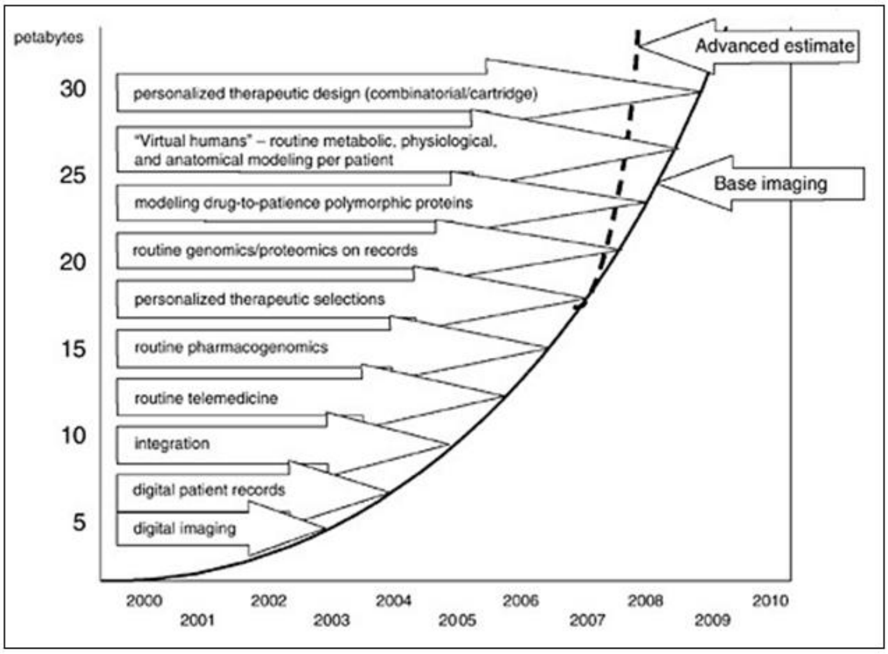

Fig-3: Life sciences data management requirements. Advanced Imaging: Optimistic projections assuming 5×10^7 accessible population with each person requiring 82×10^9 bytes by 2010–2012 [16]

Logistics

The combination of wireless connectivity, handheld computers, and inventory tracking and database software has modernized logistics. Companies in the transportation sector were the first to embrace logistics as a tool to help organize activities while improving productivity. Manufacturing and retail companies as diverse as Ford, Boeing, Intel, and Wal-Mart are heavily dependent on logistics to link together their far-flung networks of suppliers and manufacturing units. Especially in the past decade, outsourcing and "just-in-time" manufacturing have turned logistics into a tightly balanced ballet that allows companies to work across continents to develop products and deliver them at the right time and place around the world. Market success or failure hangs in the balance [17].

Logistics is being taught in an increasing number of engineering curricula and is steadily becoming a more sophisticated field. It has led to the creation of new jobs for engineers in industries and companies that traditionally did not employ them. The challenge of moving goods and services more efficiently will likely engage engineering up to and through 2020.

Nanotechnology

The next generations of engineers will continue to focus at Nanoengineering to create and manufacture structures and materials on a molecular scale. Nanostructures have been proposed as environmental cleaning agents, chemical detection agents, for the creation of biological (or artificial) organs, for the development of nanoelectronic mechanical systems (MEMS), and for the development of ultrafast, ultradense electrical and optical circuits [17]. Nanoscience and nanoengineering daw on multiple fields, as reflected in applications in bioengineering (e.g., genetic and molecular engineering), materials science (composites and engineered materials), electronics (quantum scale optical and electrical structures). In a marriage of engineering and medicine (biology) to create synthetic biology, efforts are proceeding to create a suite of fundamental tools and techniques to fabricate biological devices, analogous to those used to create microelectronic devices [18, 19].

Engineers' Commitment to Excellence and Professional Development

The quality of a person's life is in direct proportion to his commitment to excellence regardless of his chosen field of endeavour (Vince Lombardi). Engineers of today can level mountains to the ground and turn rivers from their courses. The skies and the oceans are media for a wide range of engineering activities. Various categories of modern transportation and communication systems have turned the world into a global village. Electricity and electrical energy has catalyzed civilization and environmental development. Whatever the area of human challenge, the engineers are the agents of change and innovation through well thought out engineering projects.

By the foregoing, the engineer must be engaged in continuous professional development to maintain competence and advance the existing frontiers of knowledge in their areas of practice. According to the words of Talmond Tabloid; he who adds not to his learning diminishes it, this implies that engineers should provide subordinates, the opportunities for professional development. Professionalism is also about commitment to standards of excellence in the performance of tasks in ones field of expertise. The engineer's obligations include commitments to professional development, the determination to always achieve a high standard of excellence and consistently ensuring a sound judgment in decision making.

CONCLUSION

Engineering has a direct and vital impact on the quality of life for all classes and categories of people. This implies that engineers must be professionals not just having academic qualifications. Professionalism therefore brings the engineer under the obligation to hold paramount the safety, health, and welfare of the public by performing under a standard of professional behaviour that requires adherence to the highest principles of ethical conduct. Engineering through its role in the creation and implementation of technology, has been a key force in the improvement of our economic well-being, health, and quality of life. The resultant marriage between engineering and medical (biological) sciences has brought great technological advancement in the healthcare facilities and bio-medical equipment towards improved life span and longevity, hence a reduction in mortality rate. With the prospect of the exciting new developments expected to come from such fields as biotechnology, nanotechnology, and high performance computing, engineering is profession is poised with new choices and opportunities.

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