巻頭言

Philosophy of engineering, science and society

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Global grand challenges

The global grand challenges that we face today for sustainable development include: Climate Change, Sustainable Energy, Clean Air, Clean Water, Food Supplies and Nutrition, Rapid Urbanization, Ageing Population, Infectious and Chronic Diseases, and Cyber Security. Therefore scientists and engineers are responsible for tackling these issues.

Renaissance and open mind

To cope with the current unprecedented complex challenges in economics, society, science and engineering, the spirit of renaissance should be promoted, namely to be open minded and to have courage. As Prof. Dennis Gabor, Nobel Physics Laureate 1971, pointed out: "The future cannot be predicted, but futures can be invented". What are renaissance scientists and engineers? Renaissance scientists and engineers are those who not only understand Why and How Things work but also Why and How the World works. The characters of renaissance scientists and engineers can be summarized as follows;

- Global thinking instead of local thinking;
- Circle thinking instead of linear thinking;
- Closed loop thinking instead of open loop thinking;
- Life cycle thinking instead of partial life thinking;
- Three "R" thinking (Reduce, Re-use, Recycle).

It would also be useful to understand the essence of science, engineering, invention, innovation and entrepreneurship as follows:

- Science: Discovery
- Engineering: Creation
- Invention: Realization of Ideas
- Innovation: Successful Implementation of New Things
- Entrepreneurship: Value Creation

Definition of engineering

The dictionary definition of "engineering" is the application of scientific and mathematical principles towards practical ends. Correspondingly, an engineer is a person who practices engineering. Science, engineering and technology are very closely linked and interrelated. However, there are several features that distinguish engineering from science, technology innovation.

Science is the body of, and quest for, fundamental knowledge and understanding of all things natural and man-made; their structure, properties, and how they behave. Pure science is concerned with extending this knowledge for its own sake. Applied science extends this knowledge for a specific purpose.

Engineering is the knowledge required, and the process applied, to conceive, design, make, build, operate, sustain, recycle or retire something with significant technical content for a specified purpose; a concept; a model; a product; a device; a process; a system; a service; a technology.

Technology is an enabling package of knowledge, devices, systems, processes and other technologies created for a specific purpose. The word technology is used colloquially to describe either a complete system, a capability or a specific device.

Innovation is the successful introduction of something new. In the context of the economy it relates to something of practical use that has significant technical content and achieves commercial success. In the context of society it relates to improvements in the quality of life. Innovation may be wholly new, such as the first cellular telephone, or a significantly better version of something that already exists.

Role of engineers

The role of engineers is to integrate science, technology and the business world and hence to make things happen. Science is about understanding nature and about the ways in which we can be assured that our understandings are valid. Engineering, in a broad sense, is about modifying nature. The construction of a bridge or a house, the cultivation of plants, the modification of DNA, even the creation of an organization, such as a corporation or a university, are all acts of creation that modify nature. Science is about trying to learn the whys of the physical universe and of life in it.

Engineering is about finding ways to modify that universe

Science	Engineering
Discovery, knowledge of general truth	Integration of science, technology and management to solve real world problems economically and efficiently (design under constraints)
Why?	How / What for?
Individual	Teamwork
Pursuing the first	Pursuing the best

and that life in order to extend our biological reach, the quality of our lives, and the niches in which we can survive. Thus, engineering is about how—how to go faster or slower, higher or deeper; how to fight disease; how to supply water, food and shelter; how to defend ourselves from aggression; how to better communicate with each other; how to develop social synergies; how to expand our memory, our senses, our muscles.

Whilst engineering utilizes mathematics in its methods, the kinds of complex problems that engineers face outrun mathematical methods. It is difficult to straightforwardly apply deductive reasoning to problems which involve radically different factors such as cost, safety, aesthetics as well as technical matters. Therefore, in order to solve problems, engineers look at past designs and past solutions, and draw analogies between their problem and these paradigm examples. They must assimilate other problems to the one that they face, and this involves a highly developed ability to see analogies and disanalogies.

Another characteristic aspect of engineering methods is the role of practice. Whilst in science there is a three way relationship between knowledge, theory and experiment (each element informing the others), in engineering there is a four way relationship, which includes practice. Practice motivates theory and experiment in engineering (there is a practical purpose for most research), and engineering knowledge informs, and is also informed by engineering practice. Any philosophy of engineering must, therefore, accommodate the more complex structure of engineering methods.

Engineering is the process of applying knowledge and skill to conceive, design, make, build, operate, sustain, recycle or retire something of significant technical content for a specific purpose; this might for example be a concept, a model, a development, a product, a device, a process, a system, or a technology.

Technology is the means of improving human life by the application of all knowledge and experience. The comparison of science and engineering can be summarized in the following table. The relation of science (S) technology (T), engineering (E), innovation (I) and marketing/management (M) can be expressed as the following proposed equation:

$$S \neq T$$
$$S + T + M = E$$
$$T \neq S$$
$$T + E + M = I$$

To make a successful innovation, we need to integrate technology, engineering and marketing. The criterion of success is wealth.

Nowadays engineering has become a global profession. Continuing technological advances are blurring national boundaries. Engineers of the 21st century will require greater mobility. Therefore, they need international standards of engineering education through accreditation with international recognition.

Our engineering education today should focus on preparing students to serve in the next century. However, our present engineering education is based on scientific fundamentals developed in the last century. Therefore, to reflect the changing environment, the engineering curriculum should be reformed. New fundamentals, such as environmental technology, information technology and biotechnology, should be added.

Challenges of engineering education

Amongst the greatest challenges we face in the world today are those of delivering growing, secure and affordable supplies of clean water and energy, to meet the needs and expectations of an expanding population, whilst reducing our CO_2 emissions and the human contribution to climate change. The implementation of innovative engineering solutions is fundamental to addressing the challenge of sustainable development, whilst also offering exceptional opportunities for economic growth. Yet at this time when our need for engineering talent is huge, and when our young people are increasingly interested in how they can help to save the planet, we are failing to persuade them that engineering careers are exciting, well-paid and worthwhile. The prestige and resource for teaching in research-active engineering departments have been compromised by a disproportionate emphasis on the research output as a consequence of the Research Assessment Exercise. Much more effective interaction between industry and university engineering departments is required. Support and engagement needs to operate at two levels: the provision by industry of strategic advice to help shape course development and operational engagement whereby students can experience real-life industrial engineering challenges. Universities must continue to teach 'core engineering' and not dilute course content with peripheral subject matter. The accreditation process for engineering degree courses should actively inform the development of course content to ensure that courses produce graduates that industry will want to employ. To fill the "pipeline", more must be done to ensure that school students, parents and teachers perceive engineering as an exciting and worthwhile subject that offers stimulating and well-paid careers.

Engineering the future

It is not enough to pursue the whys of nature or to find how we can modify nature. We must also decide what we should do. If engineering is to have a strong say about the future, it needs to become more integrated with science, society and humanistic concerns.

Engineering should venture to develop new capabilities and a broader sense of mission. We should integrate what we know, what we can do and what we should do. We should also be able to integrate the biological organism, society and the machine. We should strive to engineer a better tomorrow guided by the desire to give future generations a greener, healthier and more harmonious future.

Science and society

In the twentieth century, advances in social development, industrial growth and the eradication of poverty in some parts of the world have been unprecedented, mainly from technological breakthroughs.

In the 21st century, this scenario needs to be reviewed. Because the progress of science is largely isolated, single, at an unprecedented rate.

Considering the societal evolution domain is around 10,000 years, science has grown exponentially at a rate of about 7 per cent per annum, doubling every 10-15 years, growing by a factor of ten at every half-century, and by a factor of close to a million in the past 300 years. More new information has been generated in the last 30 years than in the previous 5000.

The scientific revolution has gone beyond the social revolution of more than a century. As a result of this disharmony, today the world is faced with the environment, energy, health, natural disasters, extinction, unsustainable consumption. At the same time, it creates an expanding knowledge inequality. So despite the remarkable progress in science and technology, unprecedented economic progress and improvement in the quality of life, more and more inequalities lead to knowledge inequality, thus causing troubles. Excessive consumption leads to unsustainable development. Therefore, a more inclusive view of science is necessary.

The new role of science is to address the issue of sustainable development and thus participate in social development and policy-making. Synergies between scientific and social progress. Scientific development and social development should be harmonious.

- Science: Responsible, transparent, and understanding the full impact of new discoveries on moral and ethical values and on our planet's sustainability.
- Society: To enquiry about the role of science and to recognize its importance to human well-being.

We should be harmonizing challenges related to genetic research, climate change, energy, and environment etc. with the imperatives of galvanizing the best science that can be adopted and adapted in vastly diverse geographic, social, economic, political and cultural contexts.

Therefore, the way forward should be social participation, policy intervention and enhanced international cooperation.

The new era of science should focus beyond the discovery, to solve human needs and concerns. Such as actively engaging in UN 'Millennium Development Goals' e.g. hunger, health, education, and environment. Participate with Global Change Research Program e.g. climate change, sustainable and affordable energy.

There is no single discipline, nor a single country that can solve complex global scientific problems. The complexity of the Earth system is more than we have ever known before.

In the twenty-first century, national interests and international partnerships must be seen as complementary. Therefore, we should strengthen international scientific cooperation for the benefit of mankind.

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