International Review of Applied Engineering Research.
ISSN 2248-9967 Volume 4, Number 3 (2014), pp. 257-268

http://www.ripublication.com/iraer.htm

Challenges before Mechanical Engineers

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Abstract

This article deals with advancements in engineering and its impact on human life. After listing the most important twenty advancements in the twentieth century, the grand challenges before engineers are presented. Role of mechanical engineering in meeting the challenges in the context of India are highlighted. It is concluded that future mechanical engineers will deal with large systems and projects and on the other side info-nano-bio systems. The kind of education to such engineers be provided, the curricula, contents and pedagogy are discussed. The existing curricula as well pedagogy need transformation.

Keywords: Challenges to engineers, Role of engineers, Mechanical engineering education.

1. Introduction

Throughout human history, engineering has driven the advance of civilization. The metallurgists ended the Stone Age by producing copper and iron. The shipbuilders united the world's peoples through travel and trade. Increasingly sophisticated tools for agriculture, technologies for producing textiles, inventions transforming human interaction and communication, mechanical clock and the printing press irrevocably changed civilization. In the recent past Industrial revolution impacted life and thought in a big way. Machines supplemented and replaced human labor for countless tasks. The steam engine facilitated mining, powered trains and ships, and provided energy for factories. Improved systems for sanitation enhanced health in the western world.

The technology is intimately related to economics. There is a theory in business that the economy moves in long cycles, called Kondratieff waves, driven by technological innovation. According to the theory, each of these breakthroughs spurs a long boom of rising prosperity, then a turning point and a crisis. The first such wave

came with the invention of the steam engine and the revolution in the textiles industry. The second was the building of the railways, the third in chemicals and electrical engineering. Since then economists have suggested two more, the rise of the car, and then the invention of the internet and digital technologies. There is a wave of innovation going on around alternative energy, and in the fields of biotech and nanotechnology too. It may result in sixth wave.

Whether it results in an economic wave or not, it is certain that technology definitely influences the life as we live. In essence the basic purpose of engineering is to devise, design and provide devices, machines, buildings, structures, systems and processes to promote, improve, sustain, protect or defend the material living standards of humans.

2. Achievements of Past Century

There have been spectacular advancements in various areas of technology. National Academy of Engineering {NAE}, under a project published a book 'A Century of Innovations: Twenty Engineering Achievements That Transformed Our Lives' in 2003. It documents the innovative inventions in 20 areas viz.

Electrification,	Electronics,
Telephone,	Radio and Television,
Computers,	Internet,
Imaging,	Laser and Fiber Optics,
Automobile,	Airplane,
Spacecraft, Refrigeration,	Air Conditioning and
Highways,	Water Supply and Distribution,
Agricultural Mechanization,	Health Technologies,
Household Appliances, Technologies,	Petroleum and Petrochemical
Nuclear Technology	High Performance Materials.

Contents of the book are now available on 'The Greatest Engineering Achievements' website. The website contains detailed historical information, timelines, and personal essays by key innovators for each of 20 major engineering accomplishments of the 20th century.

The impact of these developments is seen by all of us, and many experience them in daily life. The impact has been felt in all walks of life- social, economic, political, climatic environments. It has had a great effect on personal, family, and community life style a great deal. The rigour in life is eased today. Although these technological developments have made the life comfortable and more enjoyable, there are some unintended outcomes which need to be addressed.

3. What is Engineering?

Engineering is the application of scientific, economic, social, and practical knowledge in order to design, build, and maintain structures, machines, devices, systems,

materials and processes. It may encompass using insights to conceive, model, scale an appropriate solution to a problem and achieve an objective. The discipline of engineering is extremely broad, and encompasses a range of more specialized fields of engineering, each with a more specific emphasis on particular areas of technology and types of application.

Modern engineering needs close association and affinity with science and mathematics. Engineering is based principally on natural sciences and their extensions into material science, solid and fluid mechanics, thermodynamics, transfer and rate processes, and systems analysis.

The function of the scientist is to know, while that of the engineer is to do. The scientist adds to the store of verified, systematized knowledge of the physical world; the engineer brings this knowledge to bear on practical problems. Unlike the scientist, the engineer is not free to select the problem that interests him; he must optimally solve problems as they arise, to satisfy conflicting requirements in a human society. Engineers employ two types of natural resources—materials and energy. Materials are useful because of their properties. Important sources of energy include fossil fuels (coal, petroleum, and gas), wind, sunlight, falling water, and nuclear fission. Since most resources are limited, the engineer must concern himself with the continual development of new resources as well as the efficient utilization of existing ones.

Engineers create that which never was. In doing so, engineers resort to the application of science to the optimum conversion of natural resources to be used by mankind. Associated with engineering is a great body of special knowledge. Preparation for professional practice involves extensive training in the application of that knowledge.

4. Challenges Before Engineers

The unintended outcomes of past engineering solutions to the problems have adversely affected environment. Environmental sustainability, health, reducing our vulnerability adding to the joy of living is essential for humanity to flourish. This forms challenges not only for engineers but also to others.

NAE has identified some challenging areas. The challenges relate to energy and the environment, health and medical sciences, education and information technology, infrastructure and security. Through creativity and commitment these engineering challenges can be realistically met.

- Make solar energy affordable.
- Provide energy from nuclear fusion.
- Develop carbon sequestration methods.
- Manage the nitrogen cycle.
- Provide access to clean water.
- Restore and improve urban infrastructure.
- Advance health informatics.
- Engineer better medicines.

- Reverse-engineer the brain.
- Prevent nuclear terror.
- Secure cyberspace.
- Enhance virtual reality.
- Advance personalized learning.
- Engineer the tools for scientific discovery.

Meeting these challenges would be game changing. Success with any of them could dramatically improve life for everyone. However, the future solutions might depend on lowering the cost of doing things and use of less energy overall on life cycle basis.

Engineering Challenges for THE 21st Century India

The increasing dependence on technology of our standard of living requires a more technologically trained work-force with right kind of skills and attitude.

India has around 560 million people under the age of 25 years and about half of them are in the age group 10-19 years. By the year 2020 India will have 160 million people in the age group 20-24 years, much more than even China. For India next 30-40 years are useful, dynamic and productive at the time when rest of the world is ageing. India may provide workforce for the world provided they possess suitable skills on global standards. Training in technology at different levels assumes priority. Conventional methods of training may not be adequate and new technology assisted approach has to be adopted.

In R&D, India is to move a long distance still. It is not only the question of the number of persons involved in the activities, but basically the mindsets of a large number of researchers and the administrators require drastic change. Students engaged in Masters in science subjects, engineering graduates and post graduate courses and also the MBAs is the group of potential innovators on which the government, the academic faculty and the heads of Corporate India must focus. Unfortunately as on today, the standard is pretty poor.

Still a large number of people will remain unskilled and so the development of employment generating technologies /services will remain a priority for India. A vast majority of our workers of tomorrow will be ill educated and a substantial number functionally illiterate. More than 60% of those under fifteen years old enrolled in almost dysfunctional schools and more than 80% of our young engineers of today who graduate but receive little education, will be the senior professionals of tomorrow. Engineering challenges will have to include development of modern technologies that work efficiently with a large labour component, at least in foreseeable future. Low-cost and huge mid career skill up-gradation programmes would have to be put in place. Innovative use of technology in Vocational Education and Training will be a priority.

The technological challenges before India at present include the following:

- In energy area - alternative/advanced electricity generation technologies need to be made viable. There is the move to hydrogen economy. There is need of

expanding energy availability with access globally, while minimizing the adverse environmental and social impacts.

- In medicine, there will continue to be new medical testing and treatment equipment, such as prosthesis integration with the human neural system and medical application of nanotechnology to limit invasive treatments.
- In the environmental area, there is the challenge of limiting or reversing the adverse impact due to human existence at comfortable level and yet in an economically viable way.

In addition to globalization, economical sound environmental protection, and rapid technological advancement, challenges pertain to

- National security needs,
- An aging infrastructure, and
- Aging population

5. Targets of Future Challenges

While, the challenges zeroed on by NAE are applicable to others, each nation has its own priorities as per the social aspirations..

Climate, Energy and the Environment, Education, Materials, Biomedical, Communications, Water Practices and Management, Digital Divide, Transportation (personal-use vehicles), Agriculture and the Environment, Robotics, Reuse and Recycling and the Environment, Sustainable Development, Security, Water Supply, Public Transportation and the Environment are the priorities in India.

Examples of engineering challenges for India would include- agriculture technologies, new designs for railways, highways and urban transport, more efficient energy form coal, water conservation, less energy consuming housing technology with more efficient cooling systems, and affordable effluent treatment techniques, improving productivity in manufacturing, etc.

As far as health, education and "terrorism" are concerned, we should think of focusing on a more equitable, corruption-free and fair society instead of depending on only engineering solutions for our nirvana.

6. Role of Mechanical Engineers

Mechanical Engineering is concerned with the design, development, research, evaluation, manufacture, installation, testing, operation, maintenance and management of machines, mechanical and mechatronic systems, automated systems and robotic devices, heat transfer processes, thermodynamic and combustion systems, fluid and thermal energy systems, materials and materials handling systems, manufacturing equipment and process plant.

Mechanical engineers are critical to technologies that serve people and are widely represented in both the traditional and alternative energy industries. They possess the knowledge and skills needed to design new energy sources and make existing energy

sources cleaner and improve the efficiency of current and emerging technologies. They can be at the forefront of developing new technology for environmental remediation, farming and food production, housing, transportation, safety, security, healthcare and water resources. They can create sustainable solutions that meet the basic needs and improve quality of life for all people around the world.

The role of Mechanical engineers in future development will be to

- Develop sustainably through new technologies and techniques, and respond to the global environmental pressures brought about by economic growth;
- Be at the forefront of implementing a system design approach across large and small-scale systems;
- Engage in international collaboration around our critical knowledge and competencies;
- Work in the emerging Bio-Nano technologies to provide solutions in such diverse fields as healthcare, energy, water management, the environment and agriculture management, and
- Create affordable engineering solutions for the poor and deprived.

And there are aspirations of the Third World moving toward a First World standard of living in a sustainable, environmentally sensitive manner.

Mechanical engineering will evolve and collaborate as a global profession in the near future through a shared vision to develop engineering solutions that foster a cleaner, healthier, safer and sustainable world. This will need to create greater public awareness of the essential contributions of engineering to quality of life consistent with a sustainable world.

Other critical choices include focused efforts to improve:

- Advocacy to influence political decision making on issues related to science, engineering and technology;
- Multi-disciplined and systems engineering approaches to multi-scale systems;
- Partnerships among academic, industry and government to expand research and development and develop the next generation of engineers, and
- Lifelong learning for globally competent engineers and engineering leaders.

7. Sustainable Development

Mechanical engineering will be challenged to develop new technologies and techniques that support economic growth and promote sustainability. Large and growing population will need access to food and clean water, effective sanitation, energy, education, healthcare and affordable transportation. There will be global challenges to help improve the quality of life for a growing population while preserving the environment. The needs of the underserved for engineering solutions are likely to increase as population grows. Serving the population requires a restructuring of how engineers are taught to approach their profession. Teaching

engineers how to develop locally appropriate engineering solutions for the underserved is a key to developing sustainably.

Engineers in future will work at the extremes of very large and very small systems that require greater knowledge and coordination of multidisciplinary and multi-scale engineering across greater distances and timeframes A new field of systems engineering will incorporate much of the knowledge and practices of mechanical engineering.

8. Future Scenerio

Change is not easily predictable in any dynamic system. Mechanical engineering will need to monitor the rate of change across key systems such as education, industry and society. The 21st century will be defined not by conflict but by the integration of competitive markets with new methods of collaboration. The dominant players in all industries in future will be those organizations that are successful at working collaboratively. Globalization is future source of opportunity for engineers. Technology innovation clusters around leading research universities will develop. While technologies may move at a faster rate of change, institutions, cultures and economies can be slower to change. The challenges of energy, water and food are great at the global scale and they must now be addressed.

A key challenge facing every nation is balancing incentives for innovation with diffusing the benefits of innovation as largely as possible. Open innovation is a key trend as companies go for innovation wherever it can be found. Innovation, within the framework of a global economy, will remain a complex affair in future. Fundamental restructuring of the regulation and protection of intellectual property on a global basis is unlikely. As more complex technologies require greater collaboration and sharing of patents, incremental changes will occur to produce equitable and beneficial results for the innovators and those that adopt and commercialize innovations.

Demand for new technologies will sustain global demand for adequately skilled and innovative mechanical engineers in future. Prospective employers will seek and promote people with unique and varied backgrounds to maximize their potential for success in diverse cultures and situations.

Nanotechnology and biotechnology will dominate technological development in the next 20 years and will be incorporated into all aspects of technology that affect our lives on a daily basis. Nano - Bio will provide the building blocks that future engineers will use to solve pressing problems in diverse fields including medicine, energy, water management, aeronautics, agriculture and environmental management.

In future, advances in computer aided design, materials, robotics, nanotechnology and biotechnology will customize the process of designing and creating new devices. Engineers will be able to design solutions to local problems. Individual engineers will have more latitude to design and build their devices using indigenous materials and labor – creating a renaissance for engineering entrepreneurs. The engineering workforce will change as more engineers work at home as part of larger decentralized engineering companies or as independent entrepreneurs.

9. Mechanical Engineering Education

Engineering knowledge and skill is vital for the competiveness of modern societies. Innovation is the driving force behind economic growth and the key to solving future global challenges. Since economy is driven by the ability of individuals and organizations to learn, innovate, adopt and adapt fast, the education need restructuring. Apart from greater technical knowledge it will embrace knowledge in management, creativity and problem-solving.

Mechanical engineering will need to embrace partnerships among industry, government and academia to support and expand research and development and recruit and educate the next generation of mechanical engineers.

We educate and train the men and women who drive technological change, but sometimes forget that they must work in a developing social, economic, and political context. Technological choices can have unintended ethical, environmental and social consequences and therefore engineers need to be mindful of the experience of previous generations.

The issues that have been with educators for long including motivating a fresher by making the work exciting, communicating the role of engineer, interpersonal communication including writing, understanding of business processes and economic environment, professional ethics and social responsibility remain as such.

Things have changed in astounding ways affecting the environment both technical as well social. Look back to 1990 and you will recall that there was no World Wide Web; Cell phones and wireless communication were in the embryonic stage and not there in India; India was not free market economy; the human genome had not been sequenced; there were no carbon nano tubes etc. We have moved from log table to slide rules to calculators to PCs to wireless laptops in just about fifty years in India. The difficulty with common man is as O'Neil (1981) expressed 'we always underestimate the rate of technological change and overestimate the rate of social change'. The mindset influences training of engineers. In the future, most engineers will practice in national settings and in global corporations, including corporations with headquarters in foreign lands. Education should be conducive to requirement.

Partly due to the rapidly increasing power of technology, routine tasks that were traditionally performed by engineers will be performed by technicians using computers. Engineers are called upon to develop innovative products and processes, exercise new and unfamiliar technical and professional skills, and function in an increasingly global environment.

9.1 Curricula

It is imperative to shift the focus of engineering curricula from transmission of content to development of skills that support engineering thinking and professional judgment in the new environment. The U.S. accreditation agency ABET, lists targeted capabilities in a graduate engineer as an outcome criteria for accreditation.

To compete in world markets in the so-called knowledge age, one cannot depend on geography, natural resources, cheap labor, or military might. One can only thrive on

brainpower, organization, and innovation. The two likely streams of importance to humanity are:

- Bio/nano/info- The world of so-called bio/nano/info has to do with smaller and smaller spatial scales and faster and faster time scales .This frontier has to do with the melding of physical, life, and information sciences It offers stunning, unexplored possibilities Natural forces of this frontier compel faculty and students to work across traditional disciplinary boundaries This frontier meets the criterion of inspiring and exciting students out of this world will come products and processes that will drive a new round of entrepreneurship based on real products that meet the real needs of real people.
- Large systems-This frontier has to do with larger and larger systems of great complexity and, generally, of great importance to society. This is the world of energy, environment, food, manufacturing, product development, logistics, and communications. This frontier addresses some of the most daunting challenges to the future of the world.

We must prepare our students for them. Engineers of today and tomorrow must be prepared to conceive and direct projects of enormous complexity that require a highly integrative view of engineering systems. Since the "sustainable development" of human societies on this system of ultimate complexity and fragility ‘the Earth’ depends on energy - the key, we need to recharge corporate entrepreneurial and academic R&D, as well as our curricula in energy.

Also as India integrates its engineering and scientific talent into global innovation networks, Western and Indian multinationals need culturally-savvy managers adept at harmonizing and synergizing the opposing mindsets (arising out of scarcity and abundance syndromes) in their transnational R&D teams. It's time for Schools in India to start teaching to manage cross-cultural innovation networks.

9.2 Contents

The need for a sound basis in science, engineering principles, and analytical capabilities and a strong grounding in the fundamentals is still the most important thing to provide. Engineers and computer scientists are suddenly as indispensable to research in the life sciences as the most brilliant reductionist biologists. The language in the life sciences today is about circuits, networks, and pathways. The language of biology should be known to engineers.

9.3 Methods

Masterfully conceived, well delivered lectures are wonderful teaching and learning experiences and they still have their place. Studio teaching, team projects, open-ended problem solving, experiential learning, engagement in bio/nano/info research, and the philosophy of CDIO (conceive/design/implement/operate) should be integral elements of engineering education.

9.4 Role of teacher

The teachers in university may choose to act as educational philosopher and provocateur, educational researcher, interdisciplinary educator, teaching leader or scholarly teacher and reflective practitioner. Ideally, all educators would assume a role of scholarly teacher and reflective practitioner.

10.Educational Setting

The current and future generations of university students are likely to be highly impatient and need to provide deep learning through instant gratification which is challenging. However advances in information technology may come to rescue. Information technology is more or less the paper and pencil of the twenty-first century - simply there to be used, a means, not an end. The Internet, World Wide Web, and computers can do two things for engineering schools- (i) Send information outward, beyond the campus boundary and (ii) Bring the external world to the campus. By sending information out, we can teach, or, better yet, provide teaching materials to teachers and learners all over the world. By bringing the world in, we can enrich learning, exploration, and discovery for our students.

Information technology can also create learning communities across time and distance. Openness particularly at advanced institutes is creating a global meta-university, a transcendent, accessible, empowering, dynamic, communally constructed framework of Web-based open materials and platforms on which much of higher education worldwide can be either constructed or enhanced. Teaching at each university will be elevated by the efforts of individuals and groups all over the world. It will rapidly adapt to the changing learning styles of students who have grown up in a computationally rich environment.

As the research indicates cognitive neuroscience will catch up with information technology and give us a deeper understanding of the nature of experiential learning --- a real science of learning. We might see a quantum leap, a true transformation in education.

11.Conclusion

The developments in technology are a continuous process in human existence. The technological advancements have provided comfort and joy to life. But unintended outcomes of this process pose threat and need be addressed as challenge. Mechanical engineers can play an important role to meet these challenges. For that to happen proper education in mechanical engineering is necessary. The existing curricula as well pedagogy need transformation. Making universities and engineering schools exciting, creative, adventurous, rigorous, demanding, and empowering milieus are more important than specifying curricular details. While developing the concept of a new curriculum and new pedagogy and try to attract and interest students in nano scale science, large complex systems, product development, sustainability, and business realities, one must resist the temptation to push the humanities, arts, and social sciences

out of the curriculum, because the humanities, arts, and social sciences are essential to the creative, explorative, open-minded environment and spirit necessary to educate the future engineer. Engineers of today and tomorrow must be prepared to conceive and direct projects of enormous complexity that require a highly integrative view of engineering systems.

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