IEI Centenary Publication

Prof C S Jha Memorial Lecture

A Compilation of Memorial Lectures
presented in

Indian Engineering Congress

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8 Gokhale Road Kolkata 700020

Background of
Prof C S Jha Memorial Lecture

Born on the July 1, 1934 and educated at Patna university (B.Sc. Honours in Physics), Indian Institute of Science, Bangalore (D.Sc in Electrical Technology), Heriot-Watt College, Edinburgh, UK (FH-WC) and Bristol University, UK (Ph.D. in Electrical Engineering), Dr Jha started his professional career as a Design and Development Engineer at the English Electric Company, Broadford (UK) and after a two year spell (1955-57) shifted to academic life as a Lecturer in Electrical Engineering at the University of Bristol (1958-61). He returned to India in 1961 to accept a Readership at the University of Roorkee and a year later joined the Indian Institute of Technology, Delhi where he rose from an Assistant Professorship in 1962 to an Associate Professorship in 1963, a Professorship in 1964 and a Senior Professorship in 1969. He remained on the professorial staff of IIT Delhi till his retirement in June 1994. During his long academic career, he occupied several senior academic and administrative positions becoming Head of Department (1964-67) and Dean of Engineering, IIT Delhi (1966-69), Director of IIT Kharagpur (1974-78), Education Adviser (Technical) to the Government of India (1979-84) and the Vice Chancellor of the Banaras Hindu University (1991-93). On retirement from IIT Delhi in 1994, Prof Jha was appointed Chairman of the Recruitment and Assessment Centre of the Defence Research and Development Organization on a three year contract (1994-97) and later became Honorary Chairman of the Governing Council of the DOEACC Society under Ministry of Information Technology (1997-2001).

Late Prof Jha had several short and long term international assignments, He held Visiting Professorship at the Imperial College, London (1968-69), at the Technische Hochschule, Aachen (Germany) (1969) and at the Pennsylvania State University, USA (1985-87). He gave short term consultancy to UNESO in 1986 and again in 1988 in the preparation of the Draft Convention on Vocational and Technical Education and for advising Lagos and Ondo State Universities in Nigeria on the organization of their Engineering Faculty (1986). He had also been consultant to AIT, Bangkok, EdCIL, Asian Development Bank, African Development bank, World Bank and Swiss Development Co-operation on different issues of Science and Technology Planning, institutional development and curricular reforms.

Late Prof Jha had been a member of several National and International Policy making committees and had contributed significantly to the planning and management of science and Technology Education. Some of the important membership assignments were National Committee on Science and Technology (NCST) (1975-76). Review Committee on TTTIs (1975-76), High Power Committee to review Post Graduate education in Engineering (1978), Science and Engineering Research Council of DST (1980-84), Chairman AICTE Board of Post graduate Education (1990-93), High Power Swaminadhan Committee to consider resource mobilization in Technical Education (1993), High power Punnaiya Committee for financing Central Universities (1992-93), UNESCO Working Group on Continuing Education of Engineers (1973-88). Boarding Trustees AIT, Bangkok (1974-86) and International review Team for Colombo Planning Staff College for Technician Education (1983-84).

Late Prof had been a dedicated teacher and researcher and had introduced several innovations in his classroom and laboratory instruction. He has worked consistently to help his students develop creativity and problem solving skills, acquire communication ability and an awareness of quality, safety and reliability standards in their discipline, and retained an attitude for lifelong learning. He had more than 50 research publications in National and International Journals of repute on Electrical Machine Theory and Design and on Power Electronics applications and about 60 papers in National / International Conference on various aspects of Science and Engineering Education.

Late Prof. Jha had been very actively involved in the policy formulations of the Institution of Engineers, India. Since his election as a Fellow in the mid seventies, he had been a member of the Council and of CATE for most of the time except during his absences abroad. He was instrumental in initiating the Annual Engineering Congress and Annual Divisional Conventions concept, thorough revision of the AMIE syllabi in the eighties, initiating the establishment of ESCI, launching and running the mouthpiece journal Technorama for five years, formulation and presentation of Pay revision of engineers to the Fifth Pay Commission, preparation of a Perspective Plan for the Institution, conceptualizing the work of R&D Forum, preparation of the constitution of ESCI, drafting the Engineer's Bill and the documents for membership of EMF. He had been Chairman of the Delhi State Centre and of various Boards and committees of the Council from time to time including Electrical engineering Division Board and CATE. He had contributed numerous policy papers for the consideration of CATE / Council from time to time.

Prof C S Jha Memorial Lectures

was delivered during Indian Engineering Congress

Excellence in Engineering

Padmashree Dr H C Visvesvaraya

Past President, IEI

PREAMBLE

It is indeed a privilege to pay tributes to late Prof. Chandra Sekhar Jha through this Memorial Lecture; it is a special honour to have been asked to give the very first Lecture in memory of this great personality. It is a coincidence that I have known Prof Jha ever since he was a post graduate student and I was on the Staff at the Indian Institute of Science during the year 1950-1951. Though I was in a very junior position and for a very short period at the Indian Institute of Science, the then Director of the Institute Prof. M. S. Thacker asked me to take some classes and I had completely forgotten who the students were. But Prof Jha remembered and told me that I was his teacher; not only that, as I learnt from many including one of our Past Presidents Prof S.C. Naik, he has been telling in many places that he was my student notwithstanding the very small and very short contact I had with him at IISc. I am saying this for two reasons. This shows the humility and greatness of this outstanding personality. At the same time, in our tradition a Guru becomes very happy when his Sishya excels and I have this opportunity to deliver this lecture in his memory. He was personification of humility, simplicity, sincerity, and integrity.

What is generally known is that Prof Jha dedicated himself to technical education and training of our young generation in the country. But this is not all. I have had opportunities to interact with Prof Jha in almost every position he held during his illustrious career and I can confidently say that his vision was beyond education & training and was on a much wider canvas of engineering as a whole. Therefore, the National Council of The Institution of Engineers (India), while instituting this Memorial Lecture in honour of Prof. C. S. Jha, has rightly decided that the lecturer may choose any topic the theme of which should be on a subject allied to engineering and of interest to engineers irrespective of their specialization.

Achieving 'Excellence in Engineering' was close to his heart and it would perhaps be the best topic to deal with today.

EXCELLENCE IN SCIENCE, TECHNOLOGY, AND ENGINEERING

Since the main function of Science is to observe, discover and formulate the Laws of Nature, the approach required to achieve Excellence in Science is much the same anywhere in the world; except for differences in infrastructural facilities and in the working environment, scientific work is much the same anywhere in the world. The main function of Technology is to deal with the means of application of science. Its scientific content is universal but its application can get conditioned by the environment in which it has to be applied and so to achieve Excellence in Technology it could become location specific in many cases. The main function of Engineering is to convert the resources available into actual goods and services needed by the society giving due weightage to all the parameters involved whether they be in scientific, technological, economic, social, ethical, management, or even political realms by properly synthesizing them all towards a realistic and optimal solution in each case. Thus, it is clear that, in order to succeed and reach Excellence in Engineering, several parameters have to be looked at together and synthesized and optimized. Therefore, the parameters involved in EXCELLENCE IN ENGINEERING should not be confused with those for SCIENCE and TECHNOLOGY as such although there would naturally be many commonalities amongst them, and in fact, even between leadership qualities required for others in the society and those who have embraced engineering as there profession.

CARDINAL PARAMETERS OR DIMENSIONS OF ENGINEERING

The Cardinal Dimensions to be looked into for Excellence in Engineering can be explained with the help of Figure 1 and the X,Y,& Z axis therein,

X: Knowledge acquired by the engineer at any given stage and his/her ability to acquire more and more knowledge. The depth and width of these and the level of excellence reached constitute the measure for this dimension.

Y: Ability of the engineer to apply his/her knowledge for the progress and good of the society. The skills acquired, the productivity of application of the skills and knowledge to any given issue in service of the society constitute the measure for this dimension.

Z: Behavioral instincts and habits so that all actions of the engineer are within the framework of Socially Responsible Conduct of Affairs. The conduct and character of the engineer as dictated by 'DHARMIC PRINCIPLES'* (transcending all religious confinements) constitute the measure for this dimension; Indian heritage is fortunately so rich in this, if these are put into real practice in all the day to day affairs excellence can automatically be reached.

CARDINAL DIMENSIONS OF ENGINEERING

*The word DHARMIC used here should not be understood or interpreted by any one in any restricted sense but only in the sense in which it is defined by the Hon'ble Supreme Court of India which reads:

“DHARMA is that which upholds, nourishes or supports the stability of the society, maintains social order, and secures the general well being and progress of mankind”

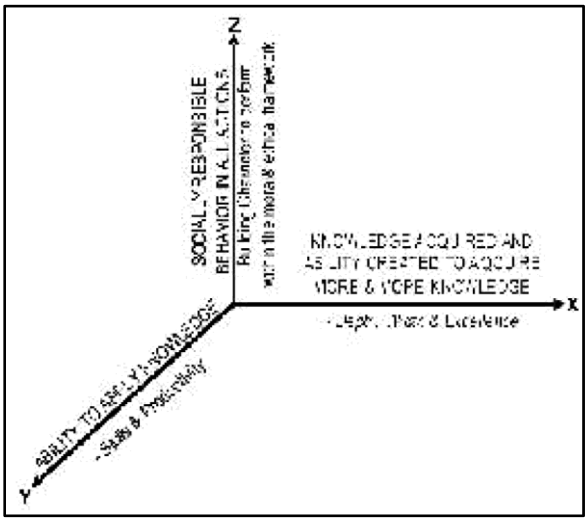

Figure 1 Basic dimensions of Excellence in Engineering

In this context, specially in the context of the third dimension mentioned above, the following thoughts expressed by Bharata Ratna Dr. A. P. J. Abdul Kalam have great significance:

“Each one of us must become aware of our higher self. We are links of a great past to a great future. We should ignite our dormant inner energy and let it guide our lives. The radiance of such minds embarked on constructive endeavour will bring peace, prosperity, and bliss to this nation”. In fact it is not only so to this nation but to every nation and every individual in every profession or avocation.

SUSTAINABLE REGIME ESSENTIAL FOR ENGINEERING EXCELLENCE

Whilst the ultimate goal of all development is expected to be the improvement in the quality of life in society, how the concept of 'sustainability' can be built into this goal is not yet precisely understood. The task of engineering is to convert available resources into goods and services needed by society for improving its quality of life. Therefore, to say that all natural resources should be preserved as they are, – undisturbed is neither a practical proposition nor an engineering reality. Successful development would many times involve some disturbances in our environment and, therefore, it is not appropriate to assume that Sustainable Development is synonymous with zero degradation; therefore, Sustainable Regime has to be understood as that regime where the endeavour is to minimize the rate of degradation and to ensure that however small a degradation that does occur is made up in the best acceptable form and as fast as possible with the aid of rapid advances in science, technology, and engineering. This applies equally to climate change issues.

The concept of 'sustainable regime' is not new; there are many examples of men of wisdom practicing it over centuries. But, a more analytical and methodical approach started with the World Commission on 'Environment and Development', commonly known as the Brundtland Commission, through its Seminal 1987 Report “Our Common Future” brought into common use the term “Sustainable Development” defining it as development towards “meeting the needs of the present generation without compromising the needs of the future generations”. Since then the term 'Sustainable Development' has been widely used, sometimes misused, and perhaps even abused on occasions. What is important for achieving excellence is to ensure that all engineering activities are carried out in a Sustainable Regime i.e. that regime which results in Sustainable Development. This would also very certainly cover the important issues relating to Climate Change.

QUALITYASSURANCE ESSENTIAL FOR ENGINEERING EXCELLENCE

The internationally accepted definition of QUALITY is:

"Totality of features and characteristics of an entity (a product of service) that bears on its ability to satisfy the stated or implied needs".

The stated or implied needs are those derived by optimizing the above stated three dimensions and the above stated sustainability along with consideration of equity worked out from the Socio-Techno-Economic considerations. This is precisely what is sought to be achieved through the processes of Standardization specially at the national and regional levels; the thus evolved National Standards provide the basis for assessment of Quality.

There is a general feeling in the public mind that Standards mean some rules or guidelines and that Standards Formulation is a routine simple job that almost any reasonably educated person or group of persons with a mandate or authority can do. It is not so. There is a lot of philosophical thinking, Socio-Techno- Economic considerations, and even political parameters in addition to scientific, technological and engineering considerations. It is only when the Standards formulated are appropriate, people get the anticipated or expected goods & services. This can be briefly explained through the aid of Figure 2 & Figure 3. In Figure 2 the three dimensions conceived by Dr. Lal C. Verman and accepted internationally are Subject, Aspect, and Level. In Figure 3 conceived by the author, the three dimensions are Technology Orientation, Transfer Interface, and System Status. It will be too long to elaborate here but details can be seen in the published papers.

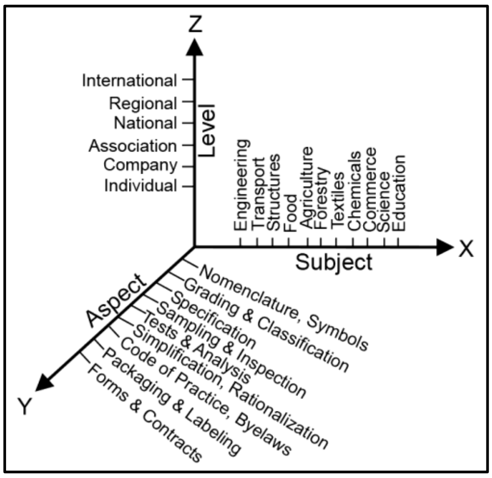

Figure 2 Verman Standardization Space concept identifying standards from structural viewpoint

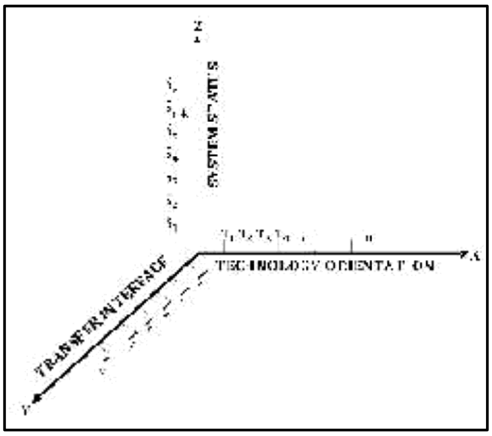

Figure 3 Visva Standardization Space concept identifying standards from functional viewpoint

Quality Compliance is achieved through the processes of Quality Assurance. There are a variety of processes to achieve Quality which are practiced at different levels in different situations by different agencies and authorities. These can be grouped broadly into the following groups:

Policing Quality	Ensuring Quality of the Final Product or Service bilaterally through mere Inspection and/or Testing.
Judging Quality	Ensuring Quality of the Final Product or Service by Involving a Third Party to provide a Certification after Inspection and Testing thus bringing a new dimension of confidence building and fairness.
Fostering Quality	Ensuring Quality of the Final Product or Service by attending not only to the Final Product or Service but also to the various stages from almost the beginning such as in recognized Certification Marking Schemes.
Growing Quality	Ensuring Quality of the Final Product or Service by ensuring that in the structure of Management of an activity or enterprise Quality Consciousness pervades and that

Quality indeed becomes a Way of Life in the whole System. There are many modern methods, approaches, and systems to achieve this goal.

It is the view of many experts, that a judicious combination of the last two systems stated above yields the best results in practice. In this framework any of the modern methods such as simple arithmetical, stochastic, six sigma and so on, as appropriate, can be used.

EDUCATION FOR ENGINEERING EXCELLENCE

Everything stated above can be achieved only through proper education. Whilst education has to be of real value, one will have to cover from the pre-KG level to Post-Doctoral level. Here again to avoid elaboration only a few aspects can be very briefly considered.

It needs hardly any emphasis to state that proper engineering education is the very foundation for meeting the three dimensions of Engineering stated above, for ensuring thatEngineering activities always remain within the Sustainable Regime, and for assuring Quality in a Global Environment, and thus deliver what is expected of excellence in engineering.

In many engineering educational institutions the entire academic programme comprises of only undergraduate courses without any linkage with research, design, and industrial & engineering activities in practice in the field. It is now well understood that an undergraduate education is better in an environment of postgraduate programme. Similarly, both the undergraduate and postgraduate programmes get better toned up when these are pursued in an industrial environment where engineering is practiced in the field or in a research environment such as those covered by doctoral and postdoctoral programmes; it would be even better if these postgraduate and research programmes are also pursued in an environment of applied research, design, consultancy, and field practices in industry or agricultural engineering.

Having stated the above broad principles, any further attempt to elaborate on Education in Engineering, would only be repetition of what many stalwarts in Technical Education have written and spoken in plenty. It would suffice here to touch upon a few matters relating to accreditation. If the parameters on which accreditation is done are sound, then the Institution or the programme accredited is sound.

For the purpose of accreditation, technical education can be evaluated or assessed programme-wise or institution-wise or for a combination of both these. Whichever of these is adopted in the accreditation process, assessment of the ability of the programme or of the institution to maximize inculcation of the three basic dimensions elaborated earlier through Figure 1 is fundamental. These three dimensions are (a) Depth, Width, & Excellence of Knowledge, (b) Skills & Productivity in Application of that Knowledge, and (c) Ability & Self Motivation to do all these within the moral & ethical framework. It is not the intention to elaborate here the details of the processes of accreditation to achieve these; it is sufficient to pointed out that the accreditation processes, when properly designed and implemented, would help in improving all aspects of education because,

(a) the Institutions would know that their programmes or institutional infrastructures and systems are independently judged in a way it would lead to their continuous improvement.

(b) the students would know what relative standing their learning in the Institution would be which would enable them to decide their preferences.

(c) those who come out of the portal of the Institution know the professional & market value of their qualification and also the extent of their acceptability in the professional world.

(d) the employers would know their new employees levels of attainments, knowledge & skills.

(e) those who fund, and the society at large, would know to what extent the funds provided are being utilized towards acceptable/ expected education.

CONCLUSION

If our country has to progress, and if our society has to provide better and happier living for our people, we should aim at excellence in whatever we do. We, who have chosen to pursue our profession as engineers, should therefore strive for achieving Excellence in Engineering.

"JAI HIND"

Prof C S Jha Memorial Lecture

Ms Maria Jesus Prieto Laffargue

Immediate Past President, WFEO

Honoured guests, authorities, Chairman of the Congress Organization Committee, esteemed President of The Institution of Engineers (India), Mr. Garg, distinguished delegates and attendees, dear Engineers, let me express my profound gratitude.

Thank you very much for giving me this opportunity to address you on this special occasion of the Indian Engineering Congress.

As an European engineer, as Past President of the Federation of Engineering Associations of Spain, and as Past President of the World Federation of Engineering Organisations, I am very honoured to deliver to you the 2nd Prof C. S. Jha Memorial Lecture, to whom, I would like to pay tribute today for his impressive and continued efforts to make Engineering Institutions worldwide relevant.

Prof. Chandra Sekhar, a visionary Indian engineer, served as an example to all of us, through his behavior and his achievements, of the need to share engineering knowledge and to promote engineering education as a pivotal tool to extend economic and social progress to all.

Before continuing I have to say, as well, that it is a real privilege for me to be here, in New Delhi, India, a country so dear to me.

You are well aware that India is a strategic country in this second decade of the 21st Century, on which, all the planet's eyes are fixed, as the things it does right and wrong, it´s mistakes and successes, will be instrumental to achieving sustainable and inclusive growth in the years to come.

This is why I don't believe I could enjoy a better setting to share with you my thoughts about the pressing issue of sustainable development.

In line with the topic of the Congress “Engineering for Sustainable Development and Inclusive Growth: Vision 2025”, my attempt this morning will be to deal with three major issues:

First, I want to speak about why our society needs inclusive growth if we want to meet the Millennium Goals and achieve the kind of sustainable development that the world urgently needs and that we envision for the year 2025.

Secondly, in a nutshell, I will mention some innovative technological applications that we are working on in Europe in the field of urban and rural sustainability

Finally, I will focus on international engineering cooperation as a pillar of inclusive growth, and on what engineers can do to contribute to it.

I will convey to you some of the lessons learned during my tenure as President of the World Federation of Engineering Organizations

To understand better why our society needs urgently “inclusive growth” let me briefly sum up the main features of this 21st Century.

At a glance, on this December 16th, our society as a whole is defined by three main features.

1. Complexity, dynamic complexity. Few things are predictable taking into account their evolution in the past.

2. Globalization, financial, social and economic interdependence.

3. Huge science and technological capital stock.

Scientific research has increased our knowledge and ability to understand almost everything in an ever wider range of space and time.

In the big picture the increasing integration of the planet's Regions, through trade and foreign investments, has brought opportunities and growth, but also challenges and risks. As a result, our society faces fourmain challenges:

– Demographic imbalances and extreme disparities in population growth.

– Tremendous disparities in wealth and access to knowledge and resources.

– Changing patterns of consumption and production.

– Adapting to climate change.

Whether we like it or not, peace and welfare cannot be achieved unless these essential issues are properly addressed for all. There is an increasing awareness that whatever happens in one country cannot be considered in isolation, but has important implications for other countries as well.

Throughout the 20th Century the world's population increased fourfold, while GPD multiplied by twenty.

The interrelated forces of globalism and technological progress are driving innovation, which boosts productivity, drives economic growth and raises living standards.

The average global poverty rate decreased from 60% to 17%, but growing inequality is one of the biggest social, economic and political challenges of our time.

Even in more buoyant emerging economies, inequality is a growing concern.

Global inequality, measured by the GINI coefficient, has begun to fall as poor countries catch up with richer ones, but in a World of Nation States – as a report in The Economist magazine has warned us -- it is inequality within countries that is growing faster and faster, and this is especially true in India.

And this is not inevitable. Don't forget that the main forces driving inclusive and sustainable growth are:

- Reducing poverty
- Increasing social capital and
- Respecting environmental ethics

That is, to develop the three pillars of infrastructure:

- Physical infrastructure
- Social infrastructure
- Economic infrastructure

And all this is up to Engineers, who can make a difference, as they are society's main actors involved in these three infrastructure pillars.

Engineers not only build the world´s roads and bridge, its electric grids and telecommunications networks, but also, their decisions are capable of altering and transforming physical landscapes and social environments.

Engineers can do things that change the world.

It is true that welfare depends, hugely, on moral and social issues, ethics in governments and Institutions, how to deal with intellectual and industrial property, among others, but engineering activity and the ethical application of the right technology lies at the very core of sustainable development and inclusive growth.

Prestigious voices here in India, in Asia, America, Africa and Europe remind us that today there is enough science, enough technology to deliver sustainable growth, and what the world needs today is to apply the knowledge we already have, to share and to use the right technology and to resolve concrete needs in concrete places.

That is, what the world needs today is engineering, more and better engineering, more and better engineers concerned with the social consequences of their technological options and their sustainability.

It is obvious that globalization and sharing knowledge about living together in concentrated and well-planned spaces offers incredible opportunities - but exclusion, grinding poverty and environmental damage create dangers.

Right now globalization must be all-inclusive and this is especially important for certain regions today.

The upheaval in values due to the extent and severity of the financial, economic and social crisis that has affected every country worldwide makes even more pressing the need to achieve inclusive growth.

Don't forget that those that didn't have anything to do with the excess and mistakes that caused the crisis are the ones suffering the most from it.

Fortunately, today's crisis will subside, and, the international economy will grow again, but, based on a different pattern, and, this is, where the dangers lie as we look towards 2025 and 2030.

According to the official data from the OECD, in the coming years India will overcome its current stagnation, and by 2025 surpassing average international growth. The world average per capita growth will be 2.6, while India will achieve per capita growth of 4.4%. India will go from representing 7% of the world total, today to 18% in 2050, with the greatest progress after 2025.

But there is a great danger of the gaps between its regions growing, with greater inequality spawning violence.

Now is the time to act. Inclusive sustainability is urgent.

Without any doubt, the new environmental and social demands, the fact that we need to do more with fewer resources, and the global population growth forecast for 2025 put unprecedented pressure on land, water, energy, waste management, access to education, efficiency and productivity.

And this places the engineering profession in the spotlight in the effort to secure and organize sustainable and inclusive growth.

This leads me to my next point.

How can innovative technologies and engineering applications work to contribute to sustainable and inclusive growth: case-studies

Allow me to start by reminding you that already, back in 1992, Nobel Laureate Gary Beeker, recognized, though intensive studies, human capital as the most valuable asset, and innovation and appropriate knowledge management as the competitive advantage of Corporations.

One year later, 1993, the endogenous development theory proved that technology, as a whole, is an internal driving force, one basic production factor accelerating business processes, economic circles and sustainable development.

Interconnected brains through information networks, and, sharing innovative Engineering applications, becomes, the most powerful economic force for inclusive growth and social progress.

Yet a radical shift is needed in how we think about and perform technological innovations.

Scientific and Technological innovations must address real questions of choice, as the STEPS Centre reminds us.

What Technology? Whose innovation?

Faster technological innovations aimed at greater social progress, promoting innovation that really works to reduce inequality, taking into account the specific backgrounds of the communities where they are introduced.

The case-studies of innovative technologies for sustainable development are very broad, both in manufacturing and services and my presentation time is limited, so I shall try to focus on select, key sectors where engineering ingenuity are vital to providing, protecting and enhancing a sustainable quality of life.

Being in India, I am forced to speak about rural and urban life sustainability and draw your attention to some field where you are almost leaders: Information and Communication Technologies:, as well as in Energy and Nanotechnology, sectors that in Spain, together with other European countries, we are exploring. Rural life is a “dying way of life” and that could sound a bit “pretentious” in this beautiful Country that India is.

As you are well aware, by the year 2050 only 14% of the population in the developed world is forecast to live in rural areas, and about 60% of the population in the developing world is expected to live in cities.

Right now half the world lives in cities. In Europe 80% of inhabitants are “urbanites” and in Spain around 70%.

Cities, as economic, cultural and social centers, generate important internal and external environmental impacts.

Cities are the primary source of global warming, greenhouse gas emissions, and urban areas account for approximately 70% of all energy use.

In the urban field the wide application of information technology can affect sustainability as a result of the complex, indirect effects that telecommunications systems have on mobility, land use location decisions, and energy consumption.

The capability to process different kinds of signals, whether, sounds, images, video and data, at high speed, in the same way, in real time, allows us to produce new applications able to be used to diffuse knowledge, to exploit the expertise of health care and training specialists located hundreds of kilometers away, and to trade with strong cost reductions and high efficiency.

The innovative information technologies that we in Europe and Spain are working on to be applied to sound urban planning and sustainable development aim to help cities improve their efficiency in terms of mobility, work, buildings, and energy, changing the way cities operate and use their resources.

- The mitigation of pollution and waste (smart buildings)
- Intelligent transport systems and the promotion of electric and hybrid cars.
- Improving multimedia conferencing systems and teleworking technologies in order to reduce traffic congestion.
- Cost-cutting for municipalities by increasing Internet access and offering municipal electronic services, monitoring and control of all municipal assets, using online tools for effective communications to and from individuals regarding sustainability.
- Integrating telecom providers into the planning process earlier in the urban planning stage.

Among them, in Spain the major efforts are being made in redirecting our transport models towards sustainability, with more efficient vehicles, different mobility patterns and the replacement of existing energy vectors.

Once again, information technologies lie at the very heart of the transformation of the transport sector.

Growing congestion is prompting radical innovations to cope with an increasingly urbanized world, and, carmakers, are working with Government and the telecommunications industry to find solutions to preserve the environment.

Now, they are looking at the vehicles on the road in the same way that they look at smart phones, laptops and tablets: as pieces of a much bigger network.

The intelligent management of fleets, the efficient provision of information to facilitate intermodality in the management of new hybrid and fully electric cars, with a central control system are some of the innovative engineering applications aimed at sustainability.

Worthy of mention are recent experiences in Spain in the cities of Madrid, Seville, Bilbao, Malaga and Barcelona. These cities have already formulated their medium-term plans, concerning, infrastructure retrofitting measures for existing buildings integrated with band telecommunications network and broad ICT's applications for:

- Dematerialization of productive processes
- Advanced logistical systems
- Smart buildings
- Intelligent electricity transport and distribution systems

With regards to rural sustainability, huge efforts must be made.

We cannot forget that, despite the urban trends, today, around 48% of the population still lives in rural areas, and even though the overall rate of extreme poverty in rural areas in developing countries has dropped, there is still, a stubborn poverty rate of some 30%, which must be eliminated through specific engineering applications.

In rural areas the implementation of advanced information technology in the fields of education, health, commerce and agriculture are instrumental to achieve inclusive growth and reduce poverty.

In Spain, already back in the year 2000, we took advantage of the digital opportunities offered by Internet applications to extend education and health in rural areas, with remarkable success. Distance learning is possible either by establishing virtual classroom in which users access a national website or by connecting to international sites.

In distance health care virtual sessions make it possible for two doctors to communicate for urgent attention, training, and discussion.

Websites can be national or international. Today, after 12 years of applying these practices, the results are remarkably successful.

Obviously, the difficulties for certain rural areas can come, with, a lack of modern telecommunications networks and the price of accessing them, is, not always, affordable

Yet, today there are more cost-effective solutions through wireless networks, packet switches equipment and IP Protocol systems which make it possible to rapidly boost teledensity and to cut prices because they can transmit voice and data over the same infrastructure at low costs.

The transmission of data and voice via satellite using very small aperture terminals works well in rural areas.

Satellites also carry national and international backbone traffic. Their cost has plummeted, and they can be rapidly installed and rolled out, delivering instant benefits.

From the point of view of ICT's innovations in engineering applications for sustainability, the opportunity is here. Yet, in order to extend their benefits to reduce poverty, other problems arise.

The small challenges in India are the variety of languages used, the stability of power supplies and the fact that information technologies are technologies that cannot be bought and used right away.

They must be adapted and integrated; they need human capital to assimilate them.

Never in the history or Humankind has the disparity, between those who are able to use these kinds of key technologies effectively, and those who are not, been so great and decisive.

Keep in mind that inclusive, sustainable growth will depend heavily on the extent of broadband access and, obviously, the existence of skilled users.

Broadband access deployment will facilitate the extension of electronic public services, an asset for countries' decentralized development.

Moreover, we have to create an understanding that progress and development through what has been called "e-society" are not at odds with preserving tradition and ethnic identity.

All of this is referring to Telecommunications-related engineering applications and information technologies for health and education in rural areas and their ascent out of poverty. What about engineering innovations for Agriculture?

In the rural world four out of five families practice agriculture, which can help them to escape poverty, but only if it is productive, market-oriented, and with access to markets, thus the importance of agri-food technology and logistical infrastructure.

Innovations, in the application of Engineering to new agricultural and biotechnological development, will be absolutely pivotal for the sustainability of Mother Earth.

There is a widespread recognition of the growing role of agriculture in building inclusive and environmentally sustainable growth.

For many countries agriculture's share of GDP exceeds 50%. Agriculture worldwide accounts for:

- 70% of water consumption
- 34.3% of land area
- 30% of greenhouse gas emissions
- 38% of total labor forces

Engineering applications for irrigation, transport, storage and waste management are crucial to increasing growth in agricultural areas.

The importance of nutrition and food security in order to secure global, inclusive growth, and, the link between energy and food lead me to mention the up-to-date technologies and innovative engineering applications in this domain.

India, one of the fastest-growing economies in the world, but with tremendous social and economic disparities, is a net importer of energy, even though, it is a leader in deep water exploration and despite its recent natural gas discoveries and its huge reservoir of scrap aluminium.

Indian authorities have difficulties:

In supplying energy power with the quality required by the highly extended digital economy in their country.

In finding the right premises required to respond to increasing demand.

In building and interconnecting the distribution and transmission lines needed to secure a dependable power supply.

In India almost 75% of the country needs flexible energy structures adapted to its characteristics.

Innovative engineering applications and improvements in renewable, distributed energy generation, "on demand hydrogen technology", and, smart grids could be instrumental for inclusive growth.

An energy supply that is sufficient and appropriate, that offers quality, and that is environmentally acceptable is closely linked to sustainable social development.

Inequitable access to energy in rural areas and the eventual exhaustion of inexpensive energy sources will have profound impacts on regional security and social prosperity.

This is why mechanisms that encourage and assist developing countries to introduce efficient and green energy technologies must be applied as soon as possible, so that they can “leapfrog” past the wasteful energy trajectories followed by today's industrialized countries.

The speedy transition to the inclusive and efficient energy scenario envisioned for 2025 entails deep and rigorous thought on the deployment of low carbon technologies and advanced fossil fuel systems, with carbon capture and sequestration.

Major research is needed on renewable energy sources, including wind, solar, photovoltaic, thermal, hydroelectric, and biomass, as is an increased effort to evaluate nuclear fusion production.

In our engineering discussions we cannot forget either the development of economic, large-scale energy storage, hydrogen cells and – as I have already mentioned – the intelligent management of distributed electricity production and distribution through smart grids.

I have to insist, here in India, on the “on demand hydrogen technology” which can provide reliable and cost-effective power in remote off-grid distributed locations.

It can help to solve the rising energy consumption.

I should also mention the importance of increased efforts in researching engineering innovations based on nanotechnology - that technology concerning processes applied to the grey area between classical and quantum mechanics, because of their relevance for new sustainable business productions, or what has been called the atomic scale industry.

Nanotechnology is relative cheap, relatively safe and clean and the benefits for sustainable development are great.

The challenge that India has to cope with for the years to come (Vision 2025) is very ambitious, as electricity will be the key energy sustainability topic until the year 2025, for, adapting to climate change and achieving inclusive growth. India should be embarking on a new phase to build an economy that is both sustainable and inclusive

Such an economy needs to add more value to the vast natural resources of India

India is today, December 2012, a Country of huge opportunities. Its economy has important competitive advantages when it is compared with other Asian Economies: legal security, transparent equity markets, qualified human resources, and a mastery of spoken English.

India, this great and lovely country, is almost a World leader in the textile industry, cement (production), the diamond cutting industry, the automotive sector, leisure and entertainment, and, obviously, software information development

Yet, India today is not only one India. It features tremendous disparities and sharp imbalances.

On one hand, Bangalore, Chennai boasts surprisingly expert telecommunication engineers and centers of technological excellence. On the other hand, rural India, which accounts for 75% of the population, accounts for only 25% of India's GDP.

The Indian subcontinent, great and unique in so many things, suffers significant shortcomings in power and civil infrastructure, which hampers opportunities to eradicate poverty, reduce mortality rates, increase education and make the benefits of globalization accessible to all.

And we, as engineers, have an obligation to be involved in the solution.

This brilliant Institution “The Institution of Engineers (India)” the largest body of engineers, must be the driving force. It must be in the driver seat.

And this leads me to the final point I would like to discuss with you.

International Engineering Cooperation as a pivotal instrument to achieving inclusive, sustainable growth

One of the major lessons learned in Rio Plus 20 in August of this year was that progress towards meeting the challenges posed by inclusive growth is inconceivable without commitments by all the World's regions.

Factors related to sustainability, such as global warming, population growth, waste management, the expansion of megacities, and changes in consumption and production patterns, cannot be dealt with without a multidisciplinary, multicultural and multistakeholder approach.

The radical shift which is needed in how Multilateral Agencies, Governments, capital funds and Institutions, operate, along with, sustainable development policies and innovations, calls for, the sharing of knowledge and expertise on how to build appropriate local capacities, and best practices in organizational processes.

Experience shows the effectiveness of international engineering cooperation and investment in innovative engineering applications that cut across engineering disciplines and cultures.

The engineering community is convinced that, there is already a very wide range of relevant, accessible and inexpensive technologies and processes available to meet the basic needs of the socially excluded.

But, in order to do so engineers must share their knowledge and communicate with decision-making Governments and Institutions about the relationship between engineering capacity building and economic and social progress.

We must improve society´s understanding of the benefits of infrastructure and engineering services to reduce poverty and increase standards of living.

The necessary reconsideration of consumption and production models poses new challenges to Governments that lack answers, and which in part can only be solved through a major collaboration by the field of engineering. But you are well aware that the Engineering profession is changing - changing in the way that it is performed and in the technologies we use.

Engineering is today a global activity.

The original idea for a project, product or services may be conceived by an engineer in one particular country, designed in one or more countries, constructed or produced with components from many other countries, and operated and maintained where it is used with international support.

Think of the Panama Canal Expansion, the Three Gorges Dam in China, or about something quite different and very close to you: the last Tata automobile rolled out here in Delhi, in January of 2008, the cheapest new car in the world, one that resulted from a complex project that involved 100 suppliers and spawned 34 patent applications.

Engineering projects, most of the time, requires collaboration by not only several engineering disciplines, but also collaboration by engineers with different social and cultural backgrounds.

Mobility, accreditation guarantees, globalization and the need for inclusive and sustainable growth are the grassroots issues of the Engineering profession in this second decade of the 21stCentury.

One of the biggest lessons I learned during my tenure as the WFEO president was that the same technology is used in very different ways in different places - and in some cases people never come to assimilate it, even after acquiring it.

And this is why the technology transfer process should be carried out with attention to the social and cultural values of the society where the technology is transferred, and in this, engineers' cooperation is vital, as the late Prof Jha taught us.

My congratulations to the Institution of Engineers (India) for following his teaching and being so cooperative and active in International Engineering Institutions, such as the World Federation of Engineering Organizations.

As Past President of the World Federation of Engineering Organisations, I am very proud of the excellent work done by Prof Lal, Chairman of the ST Committee on “Engineering and Environment”, from 1999 to 2004. The Committee under his leadership made major progress and appealed to the heart of each one of the WFEO's Members.

He participated in large, successful international events in the field of Engineering and Environment and was effective, as a voice for the Engineering before the United Nations and institutional Bodies around the world.

Allow me to remind you about the International Conference on “Sustainable development held in New Delhi in 1999”, and ,the “World Congress on Sustainable Development Engineering and Technological Challenges of the 21st Century” held in Kolkata in the year 2000.

Both shed light for the years to come on engineers' activity and sustainable development.

Right now I can only cite the WFEO Code that Prof Lal helped to write, about what engineers can do to generate inclusive growth.

1 Do your job well. Always take into account the social consequences of your decisions.

2 In your designs, development and procedures try to bring them in line with the best standards of efficiency and environmental care.

3 Be thorough, ethical and respectful.

4 Offer services, advice or undertake engineering assignments only in areas where you are competent and prepared.

5 Keep yourselves informed in order to maintain your competence. Strive to advance the body of knowledge you have, and adapt your knowledge to changing conditions.

6 Finally, learn from others, listen to others, transfer your expertise and skills to others, and transfer only clean and energy-efficient technologies so that they can grow their economies in a sustainable and inclusive growth.

To conclude

Globalization and sharing knowledge offer incredible opportunities, but, exclusion, grinding poverty and environmental damage create dangers. Sustainable development for all is no longer an option, but a must, for reducing poverty and to extend welfare and peace.

The Engineering profession is, without any doubt, the profession par excellence for the conversion of knowledge into social progress and you, as Indian engineers, are engineers from a privileged country, but, you have to be the main actors involved in the process of reducing the huge disparities in the standards of living of India's population.

You, as Indian engineers, should not accept that the greatest impediment to India's becoming a powerhouse in labor intensive manufacturing and to enjoying inclusive growth, is its appalling infrastructure and its unwillingness to implement the current technology available for the benefit of all.

It is true that it may take several years to move from an academic engineering idea, through the political process, to the drafting of regulatory small print.

But to this Institution, The Institution of Engineers (India), which, since 1920, has promoted the practice of engineering and technology in the interest of peace and welfare, and, to you engineers who made it up, let me say, humbly, to you that you have an obligation to work, along with India's Government, to reinvent India's strategic sectors and India's business production models, to focus on, and, reinforce rural and urban inclusive growth.

This great Institution is a unique Forum to promote engineering solutions to eradicate India´s inequalities.

The Institution of Engineers India must be on the front line.

In your efforts, be sure, to turn to the World Federation of Engineers Organisations for support. I am convinced that I speak on behalf of President Adel, current WFEO President

Let me finish by reminding you of the words pronounced by Indian experts during the aforementioned “World Conference on Sustainable Development”: “Reaching the unreached and including the excluded, have to be, important components of engineering and technology policy if the huge wealth of scientific and technological innovations available in our time is to become a blessing for humankind as a whole.”

I encourage you to take up that challenge.

21st Century Engineering:The Make in India Pathway

Mr A K Jha

Chairman & Managing Director
National Thermal Power Corporation Ltd

I am thankful to the Institution of Engineers (India) [IEI] for giving me the opportunity to be a part of this 30th Indian Engineering Congress here at Guwahati. A sense of purpose leads to creation of history. IEI is reaching closed to its 100 years of existence. Assam State centre of IEI is also moving close to 60 years of its existence. Organizations last long only if they continue to serve the purpose for which they were set up. The Royal Charter of Incorporation, 1935 granted by the then King of England stated that the Charter was granted to IEI, "to promote and advance the science, practice and business of engineering in all its branches in India".

It is indeed remarkable that amid changing contexts of developments and needs, IEI has grown to become a community of over 50 lakh members, encompassing 15 engineering disciplines. I am glad to note that IEI operates more than 100 state and local centres throughout the country. It also has five overseas chapters. IEI has been highlighting emerging engineering and technological scenarios through its publications. It has also been focusing on new developments, techniques, products, processes and other issues of topical interest.

Civilization is a Dynamic Product of Engineering Advancements

Engineering has always driven the growth and development of humanity right since the days of discovering fire, developing the wheel, inventing the printing machine down to the space science and the internet. The growth of different countries is also reflective of the quality of engineering available there. India and Indians live through many centuries at the same time. A successful Indian entrepreneur based in Silicon Valley travels to his village in the state of Karnataka. He uses the latest gadgets and flies in the best airlines. But he completes the last mile journey to his village home on a bullock cart. His country cousins use cowdung cake as the fuel for cooking. It is needed to maintain bridge the gap between different Indians and 'Indias'. Among the numerous solutions, it is needed to explore the appropriate engineering and technologies to suit the Indian requirements, which are very different for different geographical areas and socioeconomic segments.

As India embarks on higher trajectory of economic growth through major policy initiatives like, 'Make-in-India', the prime responsibility for enabling the country to make this massive leap, lies with the engineering fraternity. The galloping growth that India looks at can be achieved only through advanced cutting edge technology research programs in the labs and their industrial use by the engineers. The engineering community has to play a key role in enabling India's emergence as the leading power of the 21st century.

What differentiates 21st century Engineering?

Let us take a very brief look at the overall changes in the scenario since the beginning of IEI in the year 1920 or say since 1915 i.e. a century ago. This will help us outline the connotations of 21st century engineering as distinct from the engineering of the previous centuries. It will also help to differentiate the needs of 21st century India compared to those of the earlier periods. 100 years ago in the year 1915, the most important developments related to science and engineering included very important watersheds:

- Albert Einstein presented the Einstein Field Equations of general relativity.
- The first transcontinental telephone call was made. Engineer Alexander Graham Bell placed a call in New York to his assistant Thomas Watson in San Francisco, aided by a newly invented vacuum tube amplifier.
- Engineer & Chemist Georges Claude patented neon lighting tube.
- The first proper battle tank was designed which was used in the First World War.
- The National Advisory Committee for Aeronautics (NACA), the predecessor of NASA was established.

Hundred years ago, the British rule in India was at its peak and England was the most powerful nation in the world that time. Kolkata (then Calcutta) remained the most important city in India and had ceased to be the capital only four years ago that might have been the reason that IEI was founded at Kolkata in 1920. The defense requirements of the British Empire arising out of the First World War, which was fought during 1914-1918, gave a boost to the domestic Indian industry. Steel, textile and jute industries were the dominant industries. After nearly 150 years of the drain of wealth, the Indian economy had become a much smaller economy subservient to the economy of the ruling country. This was in sharp contrast to the economic significance of India at the beginning of the 19th century when it was one of the two largest economies in the world along with China.

The decline of India and China in that period of history can also be explained in terms of engineering and technology. Both these countries missed out on the Industrial Revolution which had transformed England and rest of Europe into the centre of global growth and power.

Scenario in the year 2015

I believe that the advent of internet and launching of the first search engine paved the way for new levels of learning and its integration. Thus, by the end of the 20th century, the foundations for the rapid strides to be made in the 21st century had been laid. Advancements in different areas of technology and engineering have enabled the global community to think of launching the Fourth Industrial Revolution. The 4th Industrial Revolution, which is also called as Industry 4.0 embraces a number of contemporary technologies like,

- Automation
- Data exchange
- Manufacturing

It had been defined as 'a collective term for technologies and concepts of value chain organization', which draws together Cyber-Physical Systems, the 'Internet of Things' and the 'Internet of Services'. This will characterize the "Smart Factory" of the 4^{th} Industrial Revolution that may lead to another wave of innovations, which drives the growth.

Ever since the 1st Industrial Revolution, innovation driven economies have been able to achieve or sustain high levels of socio-economic development. In other words, the innovation driven economies have led the world and other economies have been busy catching up the following slogans:-

"21st century engineering will be about innovations at an unprecedented pace"

"21st century engineering will be about competitiveness in a globalised world"

"21st century engineering will be about environmental & social sustainability of the planet & its people"

21st century engineering for the Indian Engineers

When IEI was set up, the Indian engineering community was working for and under a colonial government. Today, we are working for recapturing the glory for our country, which it enjoyed before its wealth and strength were drained away by the colonial masters. Today, India is poised to become the 3rd largest economy of the world by 2030. Indian companies in several sectors are targeting global markets and are becoming strong global competitors and are turning into Indian multinationals. Many Indian companies are already among the most competitive in their sectors.

Today, India is inviting the world to 'Make in India'. This is part of India's preparedness to become the 3rd largest economy of the world by 2030. 'Make in India' is one of the pathways leading to that destination. But thought process has to be initiated to facilitate the Make-in-India initiative, to induce it into the domestic & global industries.

Pathway to 'Make in India'

The simple answers for fulfilling the pathway of Make-in-India include,

- Strong physical infrastructure
- Strong digital infrastructure
- Strong energy infrastructure

Adequate infrastructure enables the economy to meet the requirements of the people and become competitive in the global context. In the current phase of global competitiveness, India is ranked 55th among 140 countries in terms of overall competitiveness as revealed by the findings of the Global Competitiveness Report, 2015-16 brought out by the World Economic Forum (WEF). Among the BRICS (Brazil, Russia, India, China and South Africa) countries, China at 28th rank, Russia at 45th rank, South Africa at 49th rank are ahead of us whereas only Brazil at 75th rank is behind us. As per the report, 'infrastructure', 'technological readiness' and 'innovation' are among the identified factors or pillars of competitiveness. On the parameter of infrastructure, India is behind all other BRICS nations with 81^{st} rank whereas Russia at 35, China at 39, South Africa at 68 and Brazil at 74 are ahead of us. On the parameter of technological readiness, India is at an extremely low rank of 120 as against South Africa at 50, Brazil at 54, Russia at 60 and China at 74, with all other BRICS nations ahead of us. Although, the other BRICS nations too are not very highly placed. On the parameter of innovation, India is at the rank 42. China at 31 and South Africa at 38 are ahead of us whereas Russia at 68 and Brazil at 84 are behind us.

The recently released ICT (information, communication & technology) Development Index, released by International Telecommunication Union (ITU), which works under the UN system, places Korea 1st among 167 countries while India ranks a lowly 131st. Russia at rank 45, Brazil at 61, China at 82 and South Africa at 88 are ahead of us.

The engineering community has to play its part in enhancing the size and improving the quality of physical, digital and energy infrastructure. It has also to play a key role in improving India's performance on the parameters of technological readiness and innovation. In fact improvements in all these areas are inter-related and mutually reinforcing. Out of the physical, digital and energy infrastructures, energy is the prime mover, which enables growth in other areas and is also necessary for operation of practically all the modern inputs and facilities. Among the energy sources, electricity is by far the most versatile in terms of extent and ease of use.

Electricity: among the key drivers of make-in-India

Electricity is both the prime mover and also the prime indicator of economic growth. According to the World Bank Development Indicator (WDI) data for the year 2012 published in 2015, Russia's per capita electricity consumption of 6617 kWh, South Africa's 4405 kWh, China's 3475 kWh and Brazil's 2462 kWh were far higher compared to the paltry 744 kWh for India. This is a major drag on India's development efforts, more so for the manufacturing sector. Electricity will be among the most important factors in powering the make-in-India initiative. The success in making mobile telephony available to nearly 100 crore people in India was possible because of affordability of tariff and availability of cheaper handsets along with the wide network of transmission infrastructure. Appropriate technological and engineering initiatives are required to make electricity affordable and accessible to the largest possible population of the country.

Making electricity accessible and affordable is far more difficult and complex compared to mobile communication. The factor of environmental sustainability further compounds the challenge. The pathway to make-in-India has to negotiate the challenge of reconciling the necessity of using coal as the mainstay of India's energy needs and meeting the environmental expectations in terms of carbon emissions. Electrical energy is the key factor of production for manufacturing and hence providing not only reliable but cheaper power to industry is paramount for making India a manufacturing hub. It is a fair argument to say that in per capita terms India deserves a larger amount of per capita carbon space in view of the fact that its per capita CO_2 emissions are only 1.5 tonnes as compared to 16.2 tonnes for US, 10.8 tonnes for Russia, 9.7 tonnes for Japan, 6.6 tonnes for China and 4.5 tonnes for the world as a whole. Yet as a responsible country, we have taken upon ourselves the task of making coal based energy as clean and efficient as possible and at the same time rapidly increasing the share of non-fossil energy.

The context in which, India is seeking to grow rapidly can be seen in some of the basic facts which influence its policy and action frame work,

- India houses approx. 30% of global poor population
- Close to 300 million populations in our country still have no access to electricity
- India plans to reduce carbon intensity of its GDP by 33- 35% from 2005 level by 2030. The development – environment interface is being distorted in a manner that the industrialized countries seem to replace the 'polluter pays principle' by an approach which may amount to some kind of a 'victim pays principle'. India is at the centre of this debate.

lThrough make-in-India initiative, it is intended to increase the manufacturing contribution from the current level of approx. 15 % of GDP to roughly 25% by 2025.

Huge power generation capacity is required to fuel such growth. For GDP growth of 8% to 9%, power generation capacity has to be of the order of 800-900 GW by 2031-32. The current installed capacity is about 280 GW. With a production of about 1100 tWh India is the world's fifth largest producer and consumer of electricity. A total demand of 1905 tWh is expected by 2022. Impetus on developing industrial corridors, smart cities, make-in- India and other such initiatives will bear fruits only if supply of reliable and quality power is ensured.

The challenge before power sector is to deploy advance technologies with the objective of reducing carbon intensity and at the same time provide power at competitive rates. This balancing of affordable price of power with reduced carbon intensity has become more challenging with the rapidly increasing share of renewable energy. It is to be searched out the new ways of grid management and price management in view of the rising share of renewable energy.

Renewable energy: from margins to main stream Greenhouse-gas emissions from the energy sector represent roughly 2/3rd of all anthropogenic greenhouse-gas emissions and CO_2 emissions from the sector have risen over the past century to ever higher levels. This is the observation of International Energy Agency (IEA). The 21st century energy solutions have to be provided keeping in view this grim fact. Giving primacy to renewable energy is necessary for keeping CO_2 emission at relatively lower levels.

There is a paradigm shift in power development program of the country. India has embarked upon a massive renewable capacity addition mission of installing 175 GW renewable energy capacity by 2022. Out of this, 100 GW is going to be solar capacity, which is unprecedented.

Today about 4 acres land/MW is required for Solar with capacity utilization of about 17% to 20%. Putting up 100 GW of Solar will require huge chunk of land. In this regards, it is to be thought about the probable innovates like,

- Can we further improve our panel efficiency?
- Solar thermal promises higher efficiency and scale-up but has high cost.
- Can we reduce the cost of solar thermal?
- Solar thermal can be far more effective with appropriate storage.
- Can we develop effective storage methods?
- Can we think of developing an appropriate reflecting surface and a fluid which can store more heat energy?

In addition to setting an ambitious target for solar capacity addition, India has also set a capacity addition target of 60 GW for wind power. The capacity utilization factor wind power projects ranges from 25% to 40%, depending upon various wind zones. This massive capacity addition program in renewable energy space also opens up vistas of opportunities in India to churn out innovative solutions to reduce cost of generation from solar and other renewable sources to make them affordable. At the same time, major focus is required for developing technologies to minimize emissions from coal based power generation because coal will remain the mainstay of India's energy supply for many decades to come.

Clean coal technologies for lower CO_2 intensity

While the share of renewable energy sources is being rapidly ramped up, it is also important to note that the electricity from those sources is not available for 24 hours. Typically, power from a solar plant is available for about 7-8 hours. Availability of power from a wind power project depends on the wind velocity and is therefore, intermittent in nature. In order to supplement the addition of 100 GW solar capacity, which will serve for only 7-8 hours we need the balancing power for the remaining 16-17 hours. Similarly it is needed to provide the balancing power for the 60 GW, new wind power capacity to be added which is alsointermittent in nature.

Large Hydro plants have their own ecological implications to provide the gas. At one point of time, large number of people needs urgent access to electricity. For this, use coal was essential.

The need for using efficient and clean coal technology is the need of the hour. We have been upgrading and adopting our coal based power generation technology from sub critical to super critical and ultra super critical. The unit sizes have steadily risen from 110 MW to 200 MW, 500 MW, 660 MW and 800 MW. Plans are under way to increase it further to 1000 MW size.

Steam parameters, which have a direct relation with the efficiency of coal energy utilization, have been steadily increasing. The earlier units were based on subcritical technology (with operating steam parameters of 150-170 kg/cm2 and temperature of 535°C). Unit size ramp up, reheat steam increase to 565°C and equipment design improvements have led to increase in conversion efficiency. For cleaner use of coal, we have adopted super critical technology with steam parameters of 247 kg/cm^2 and temperature of 593°C. It offers improvement of about 2% points over the sub critical technology primarily due to increase in operating steam temperatures. This translates to about 5% reduction in CO_2 emissions. To push the efficiency values even higher, NTPC is now inducting units based on ultra-super critical technology where the operating steam temperature nears 600°C. The efficiency of these units is in the range of 42% which is 4% points more than the sub critical units. This higher level of efficiency results in reduction of CO_2 emissions to the tune of 10%. In fact ultra-super critical technology with temperature up to 600°C is now being specified for all new 600, 800 and 1000 MW units by NTPC. In order to further increase the parameters to enhance efficiency, NTPC is playing a key role in the development of Advanced Ultra Super Critical (AUSC) project It is collaborating with Indira Gandhi Centre for Atomic Research (IGCAR) and BHEL on this project. The project envisages development of indigenous technology for steam parameters of 310 Kg/cm^2 and 710°/720°C temperature. Such parameters are way higher than steam parameters used in contemporary plants globally. These parameters would result in top-of-the-line efficiency of 46%. This is a sharp increase from the contemporary efficiency levels of 38% in the sub-critical

500 MW units and of 40% in the supercritical units. It will result in reduction of CO2 emissions to the tune of 20% compared to a sub-critical plant.

The project aims to execute a 800 MWe AUSC coal fired unit in a 7 year period out of which 2½ years are earmarked for design and development work (R&D phase) and 4½ years of power project construction phase. In the R&D phase, the focus will be on development related to materials, design, manufacturing techniques, testing of those power plant components which are impacted by high steam parameters e.g. boiler tubing, headers, critical piping, HP/IP turbines, valves and other such equipments. We will also work on characterization and indigenization of advanced alloys which have been identified for high temperature application in the project.

In the meanwhile active work on the certain critical areas like, hot corrosion testing of new materials for boiler, turbine blades design, Super heater header, HP bypass valves, mock water wall panel etc. has already commenced in the form of pre-project R&D. Some of the components like, indigenously developed high alloy tubes, high pressure bypass valve are proposed to be tested in NTPC Dadri and other power stations. Subsequent to completion of R&D phase, 800 MWe unit based on indigenously developed AUSC technology will be set up. Once set up, the efficiency levels of this unit will far supersede any other coal fired unit worldwide. However, in the area of AUSC Technology, no country has reached the stage of commercial use. India is one of the very few countries engaged in R&D on this technology. Those few countries who have started R&D on it before India and have reached a certain level of learning should share it with us so that all the countries having different levels of progress in AUSC Technology can integrate their efforts to achieve the break through as early as possible. Developed countries need to transfer this and other technologies as well as financial resources for the world community to collectively deal with the climate change challenges. Another path for efficiently using the coal is to bring in higher efficiency gas turbine cycles while maintaining coal as the fuel. This is important due to meager natural gas availability in India. NTPC has been working on Integrated Gasification Combined Cycle (IGCC) technology that uses a high pressure gasifier to turn coal and other carbon based fuels into pressurized gas-synthesis gas (syngas). This gas is then fed to gas turbine. This technology seeks to make use of higher efficiency offered by gas turbine. Globally, there is limited experience related to such power plants. Also the commercial viability of such plants is yet to be established. Indian engineers, in collaboration with the global community of engineers, have to find ways of making such technologies commercially viable in India.

Indian engineers to find solutions for the country

Preliminary assessment indicates that the fund requirement for implementing India's Intended Nationally Determined Contributions (INDCs) will be approximately USD 2.5 trillion between 2015 and 2030. While the need for global cooperation is essential to effectively meet the energy challenges of countries like India, it must be understood that we have to find our own solutions without waiting for the global community to change its approach. Indian engineers have to find Indian solutions to Indian problems. Whether it is supply side or demand side, engineering solutions can help in reducing cost and improving performance. This is the expectation of the country from its engineering community. In fact India has the largest pool of technical manpower in the world. Yet India has very few patents. We need to change this. Our engineering community must strive for creativity and innovation. We must have much larger number of patents. We must have much bigger intellectual capital in terms of total Intellectual Property Rights (IPR). This endeavour of substantially increasing the number and value of IPRs available in India is going to be a part of the process of making India a strong global power.

Innovation with Indian characteristics: We need innovation by the Indians, for the Indians

Frugal and efficient use of natural resources has been a hallmark of the Indian tradition. In fact the millennial civilizations of China and India thrived in a sustained manner because of their alignment with the nature. Today the world is coming back to realizing the necessity of minimizing the pressure on the natural resources. There is a need to again focus on the homegrown, simple, effective, and flexible solutions to the energy problems. Flexible would mean, to some extent, the capacity to adapt to the local surroundings and need. It can also mean customization to meet the unique requirements of a particular habitat. Doing more with less has been the approach of the innovators. In other words, efficiency is naturally built into innovation. However, today we need to do most with the least. Every gram of coal has to generate maximum power. Every drop of oil has to give maximum mileage. And this is to be done with least emissions. This is to be done along with finding the most innovative ways of trapping solar energy which is so abundantly available in our country. Similarly, other sources of energy also need to be exploited with utmost efficiency with the help of homegrown innovative energy solutions.

India is very different from the developed countries in terms of levels of income as well as energy requirements and use. Hence,India's energy solutions have to be different from those applied in the industrialized West. Devising our own solutions will be possible only through innovations which use Indian resources, which cater to Indian needs and which are affordable to the largest possible segment of the Indian population. Recently, the

Power Minister of India exhorted the engineers and industrialists to find ways of reducing the cost of production of LED bulbs in the country. This will help increase the use of LED bulbs and thereby reduce electricity consumption for lighting purposes. India's drive to popularize use of LED bulbs has been highly successful.

Already, the price of LED bulbs has come down from about Rs.300-400 to less than Rs.75. Yet in order to make its impact even bigger, there is a need to further reduce the cost of LED bulbs. Innovative thinking can definitely help in further reduction of the cost of LED bulbs for the buyers in the Indian market. The success story of solar power in India includes the fact that Cochin International Airport has become the world's first fully solar powered airport. Such achievements are powered by the thinking to move towards a cleaner environment with the help of innovative methods. In fact innovation has to be made a central strategy in devising energy solutions for India.

Major companies in the west are talking of reverse innovation. Reverse innovation simply means innovation rooted in the developing countries. In order to capture growth in emerging markets, those companies now think of innovating in those markets rather than only exporting to them. They are keeping the emerging giants like India on their radar. They are planning to move their people to the developing countries. They are creating a reverse innovation mindset throughout the corporation. Their strategies include commissioning of Local Growth Teams (LGTs) stationed in countries like India. When the western countries are trying to have innovations grounded in countries like India, it is all the more necessary that we take up innovations based in our own country in a big way.

Many leading global companies have their R&D arms located in India, and are powered by Indian brains. We have to create conditions to leverage such a rich pool of technical expertise for national purposes through innovative engineering. Innovative energy solutions are extremely important for dealing with the energy challenges facing India. These energy challenges are closely linked with the challenges on the front of climate change.

A Framework for 21st Century Energy Technologies in India Future technology interventions in Indian power sector are envisaged to address 'Unique Issues requiring Customized solutions'. A few of these 21st Century Technologies are briefly described below,

Low Grade Heat Utilization

- In any coal fired boiler, around 40% of input energy is converted to electricity, balance 60% energy is lost. Around 36% of the lost energy goes out through chimney as flue gas and the remaining 64% is lost in cooling tower.
- In the western countries, which incidentally are also cold countries, 'district heating' is required as much as electricity – this pushes up the overall coal energy utilization to 70-80%.
- India is a hot country and therefore 'heating' is not an option for us.
- Also, losing around 60% of the coal energy is definitely not acceptable. We need to develop technologies which can efficiently and elegantly use the 'Low Grade Heat'. Some such technologies are mentioned here:
    - Flue Gas Air Conditioning: Flue Gas is used to produce hot fluid. This hot fluid is used in Li-Br based 'Vapor Absorption Machine' OR Silica based 'Vapor Adsorption Machine'.
    - Flue Gas Desalination: Flue is used to produce ultra LP steam (0.34 ata, 72°C). This steam is used in a MED (Multi Effect Distillation) chamber to produce distillate from either waste sea water or cooling tower blow down water. This distillate, depending on need, can be converted to either DM Water or Drinking Water.
    - Flue Gas Organic Rankine Cycle: Thermal energy of flue gas is transferred to an 'Organic Fluid'. Typically this 'Organic Fluid' is a mixture of iso-pentane & isobutene and has very low boiling point. Therefore,even for flue gas temperature of 130-140°C, 'Organic Fluid' attains a pressure of around 24 ata which is adequate to rotate a turbine to produce power.
    - Flue Gas Fuel Oil Heating: With an intermediate fluid, flue gas can be used for Fuel Oil Heating.
    - Flue Gas Condensate Pre-heating: A part of condensate is made to bypass LP Heaters in a controlled manner and pick heat from flue gas between APH and ESP. This results not only in integration of waste flue gas heat to the main condensate cycle which in turn boosts the MW output – but also in better ESP & ID Fan performance due to low flue gas temperature.
    - Heat Pumping Technologies for CW: CW temperature exiting condenser is quite low (around 42°C) and cannot be used directly in any thermodynamic cycle due to 'exergy'. This brings in the requirement of 'Heat Pumping Technologies' e.g Metal Hydrides. This would improve the CW temperature and therefore make several of the existing thermodynamic cycles viable. It would be worth mentioning that a lot of work still remains to be done in this domain.

Concentrated Solar Thermal (CST) Technologies

21st Century Technologies in the field of CST technologies can be broadly divided into following heads:

- Intelligent Integration of CST with Industrial process: This domain contains large number of technologies. Very often, each of these technologies would require customization as per local ambient and topography conditions. They are:
  - Solar Thermal Air Conditioning System
  - Solar Thermal Desalination System
  - Solar Thermal Multi Mode Cooking System
  - Solar Thermal Space Heating System
- CST for Power Generation: Other than the 'stand alone' CST power plant, advanced work is being done in following areas,
  - Solar Thermal based reformation of Natural Gas to increase Hydrogen content – CSIRO, Australia has taken up a pilot project.
  - Solar Thermal based Super Critical CO_2 Cycle: Scandia Lab, USA has already setup a 10 MWe s-CO_2 cycle. They are in advanced stage to couple it with CST. In India, IISc Bangalore & BARC are spearheading similar effort.
  - Solar Thermal based catalytic Water Splitting & coupled with Hydrogen Fuel Cell - Scandia Lab, USA has setup a pilot facility.
  - Integration of Solar Thermal with Coal /Gas based Power Plant - Setup at Liddell Power Station, Australia. NTPC is also setting up an integrated Solar Thermal- Coal Hybrid Plant at Dadri where the targeted efficiency is around 24-26% compared to 18-20% achieved in a standalone solar thermal power plant.

Development of Critical CST Technologies

- PCM (Phase Change Material) based TES (Thermal Energy Storage) – Upon development, PCM-TES is likely to be the most cost effective 'Bulk Energy Storage'. This would not only address issues of transients (cloud cover etc) but also intermittency of operation (operation during lean /non solar period).
- Indigenous Solar Thermal – Summation of parts in Solar Thermal Technology is 30-40% of the commercial cost of plant which implies that the cost of knowledge is high. Therefore development and ownership of the 'Indigenous Solar Thermal Technology' shall help the case and bring down the cost of Solar Thermal.

Solar Photovoltaic

- lConcentrated Photovoltaic: Space based PV technology - Gallium Arsenite based Solar cell instead of conventional Silicon – module efficiency 28-35% compared to 17% of silicon PV.
- lFloating PV: Low cost HDPE floaters – water bodies can be used for PV installation – Within NTPC, 5089 acres of water body is available where 700 MWp PV can be installed.

The way forward

India has managed to become the third largest economy in the world in PPP terms. It is poised to become the third largest economy in dollar terms also by 2030. Engineers in today's rising India are much better placed than their predecessors to contribute to its growth and development. India is in a position to become a part of the fourth industrial revolution. India has to leapfrog to become a major partner in the fourth industrial revolution.

The 'Make in India' initiative launched by the Government of India provides a platform for the engineers of India to prepare the country quickly for the next wave of technological and engineering innovations. On the front of sustainability, there is good news pointing towards a cleaner future. According to the World Energy Outlook Special Report captioned 'Energy and Climate Change', brought out by the International Energy Agency, the global economy grew by around 3% in 2014 but energyrelated carbon dioxide (CO2) emissions stayed flat, the first time in at least 40 years. We have to make concerted efforts to provide strength to all the developmental endeavours like, the make-in-India initiative while keeping the emissions extremely low and wherever possible, achieve carbon-neutral growth.

Challenges and Opportunities for Professional Societies

Prof K K Aggarwal

Former Vice Chancellor, GGS Indraprastha University, Delhi
Former President, IETE and CSI

At the outset, I express my gratitude to The Institution of Engineers for having invited me to deliver 8th Prof. C. S. Jha Memorial Lecture during their 33rd Indian Engineering Congress at Udaipur. I consider it a great privilege and thank all my Engineer colleagues for bestowing this honor on me. According to me, the Memorial Lecture should really try to extrapolate to the extent possible what Prof. Jha would have said, had he been with us today.

I had known Prof. Jha very closely and had frequent interactions with him, spanning several decades, on various Engineering aspects and even more about Quality Engineering Education. I, therefore feel I can do some justice to this Lecture and I shall try my best to come up to your expectations by expressing my thoughts on a range of issues. Also, the theme of this Congress 'Integration of Technologies : Emerging Engineering Paradigm' is so dear to me that I am tempted to share some thoughts on this theme also as I feel this Integration is no longer a luxury; it is now a must for survival.

By virtue of my greater experience with The Institution of Electronics & Telecommunication Engineers (IETE) and The Computer Society of India (CSI), I have opted for a generic topic relevant to most Professional Societies. However, I shall try to be more specific and direct towards the Institution of Engineers (India), which is the largest of all and hence has the largest share of responsibility also.

My very simple definition of an Engineer is scientific and creative problem solver and in this context, I see the following challenges before the Institution :

1. To cope up with the fast change, which is unprecedented at present.

2. To come out of the traditional discipline boundaries and encourage diversity in all its forms.

3. Not to accept the status quo, unless its validity at present is confirmed.

4. To ensure the quality of Engineering Graduates being produced in the Country.

5. To ensure that Creativity is appreciated over Conformance.

6. To ensure that Engineers are able administrators and make the public appreciate the same.

In the light of these challenges, which might appear formidable, I see the opportunities with a far greater significance, if we make the right moves at the right time – which is TODAY. Some of these opportunities are :

1. To be an active partner in the Accreditation of Engineering Programs, being conducted in the Country.

2. To Register all practicing Engineers and all graduating Engineers and to devise ways & means to ensure updation.

3. To hand hold Institutions conducting Engineering Programs, which are found wanting.

4. To supplement Engineering Education, as against only a means of substituting mode of delivery of Engineering Education.

5. To be the most active partner of organizing hackathons for Engineering Students and young engineering teachers.

6. To synergise with all other similar professional societies to ensure a dignified slot in the national landscape.

Today, even political independence of any country is linked with economic and technological independence. Any developing Country, which keeps itself dependent upon other (developed) countries for its needs in strategic sectors runs a great risk, even of survival and existence (not to say of becoming a developed nation). This pushes us further down in terms of strategic self reliance.

Some focused areas of Engineering Education are to be attended to right now to ensure we have adequate quality man power available when we move strongly towards the development of Robotics, Internet of Things, 3D Printing, Use of Artificial Intelligence, Nanotechnology, Cloud computing, etc. A comprehensive Engineering Education will be the requirement for effective solutions towards Climate Change, Inland Water Transport, Infrastructure development, Cyber security, Use of Block chain Technology. The new job areas anticipated are such that the levels of skills needed for any job will require a quantum jump and we have to be ready for this straightaway.

The Engineering Education in the Country will need new models with a clear shift towards integrating knowledge and skills in right proportion for the specific job and for the intrinsic capabilities of the student. The Engineering Education should also concentrate on the solution of local and regionalproblems, as these will be more beneficial to India with a large percentage of rural population. Design of new courses for our SMEs particularly and for small start ups is a requirement now and the Institution will have to come forward.

By and large, our academic Institutions are so far focussing on Publications instead of Products. This results in a situation, where National missions like, 'Make in India', are not getting the due benefit of inherent R & D potential of the scientists & academicians of the Country. This situation is not thus challenging the Engineering Higher Education System to go in for drastic changes and that too fast enough. Unless timely steps are taken, it may be too late in the day. Fast growth of service sector in India, though very welcome move had no reason to render us complacent in manufacturing sector and not demand a fair share of creativity and Innovation. India is a Country full of talent which can rise to any occasion and our internal demand of any good quality product can be very high. These factors should have been enough to boost R & D in the design & development of high quality, energy efficient, eco-friendly, cost effective and sustainable products. It has not happened and I emphasize that we can not lose any more time.

The 4.0 Paradigm and Technical Education

Mr BVR Mohan Reddy

Executive Chairman, CYIENT, Hyderabad

"Education is not the learning of facts, but the training of the mind to think." – Albert Einstein (1879-1955)

At the outset, let me thank The Institute of Engineers (India) or IEI for giving me this opportunity to deliver the 9th Prof C S Jha Memorial Lecture.

Prof C S Jha was a well-known academician and worked extensively on electrical machines, control systems, and energy conversion. Prof Jha was an eminent administrator and provided leadership as Director of IIT Kharagpur and later as the Vice Chancellor of Banaras Hindu University (BHU). It is an honour and privilege for me to deliver this Memorial Lecture. While I tried to research on Prof Jha, I came across the monumental research (published in 2010), he did along with Prof Gautam Biswas, Prof K L Chopra and Prof D V Singh on "Engineering Education". It was a project sponsored by Indian National Academy of Engineering (INAE). It was a comprehensive document covering the status of engineering education in India, its challenges, and the suggestions on instituting healthy governance in educational institutions. Since the publication of this report, it got printed as a book too. I was reflecting on this work and the current engineering education scenario in India. By an interesting coincidence in 2018, AICTE appointed an expert committee to develop "A short-term perspective plan for engineering education in India" where I chaired the committee.

The expert committee researched extensively and collected data on the current state of engineering education from several sources, analyzed, and recommended several reforms to AICTE. The recommendations covered capacity utilization, emerging trends in engineering disciplines, improving employability, faculty development, and improving pedagogy. It covered the use of technology in education, advocated deeper collaboration between industry and academia in research and faculty exchange, and industry representation on advisory boards. Further, the report stressed promoting entrepreneurship and research in future engineering trends. AICTE accepted this report, and based on the recommendations, it launched several initiatives. The engineering curriculum is being overhauled as we speak today and new courses in digital technologies are being introduced. Faculties are undergoing crash courses on digital technologies and teacher-training programs and certifications are becoming mandatory.

The perspective plan we developed was more on immediate actions. As I look into the long term, I see several socioeconomic challenges that have a bearing on our education system. That apart, the advent of disruptive technologies and the consequent meeting of cyber and physical worlds are giving way to the Fourth Industrial Revolution or Industry 4.0 as it is popularly known. Silently and simultaneously, two other changes are taking the world by storm – Globalization 4.0 and Education 4.0. While globalization continues, we have seen different countries recovering from 2008 global economic meltdown at different paces. We have also been witnessing an increasing disparity between the haves and have nots. As a result, countries are becoming protectionist leading to trade wars between nations. The trade tensions among United States, China and Britain's exit from the European Union are a few examples. Countries today want to be self-reliant as much as they want to be globalized.

In parallel, technology shifts are bringing about major shifts in learning. Education 1.0 was more about a gurukul, centered around the knowledge of the teacher. Education 2.0 came with the advent of the printing press, which made knowledge accessible to many outside the classroom. Education 3.0 came when television transmitted classroom lectures to remote students. But, these were at fixed timing and were one-way communication. However, they certainly helped distance education in a big way. Education 4.0 is a response to Industry 4.0 and places the student at the centre of the learning ecosystem. Technology enabled the student to access the courses of the world's best teachers online and learn from anywhere and at any time. The backend AI engines enabled the learning platforms to create personalized and flexible learning paths. Increasing life expectancy and consequent longer work spans of individuals, and dynamically changing industry requirements are compelling working professionals to upgrade their skills constantly. So, life-long learning has become the norm of the day and yet another paradigm shift in education.

All three 4.0s are bringing about tectonic shifts to learning and compelling the current higher education system to change and adapt to the new reality. In this lecture, allow me to highlight seven core issues in today's engineering education:-

1. Periodic Curriculum Updates: Since the advent of the first industrial revolution in the second half of the 19th

century, technology has been increasingly contributing to GDP and improving the quality of life and well-being. Technology changes started accelerating in the latter part of the 20th century largely because computers became faster, smaller, and cheaper and connectivity improved multi-fold. Connected people and things started powering the network; Miniature sensors (which can sense all the five senses of human being fairly and accurately) began creating enormous amounts of data. Algorithms on this data led us into AI, machine learning, etc.

The application and benefit of these new technologies are further amplified and democratized with ease of access to technology, innovation, globalization, and entrepreneurship. These technologies became all-pervasive and have found application in every industry without exception. Products and services became interdisciplinary and didn't sit in silos. For example, today automobile engineering is not only about mechanical engineering and moving parts. The current generation electric vehicles require electrical and electronics engineering, embedded and application SW, energy storage, etc.

In this fast-changing world, we need to ensure future engineering graduates are ready to address the challenges brought about by new technologies. As of now, some of the new technologies that are identified are Artificial Intelligence (AI), Machine Learning (ML), Big Data and Analytics, Augmented Reality/Virtual Reality (AR/VR), 3D Printing, Internet of Things (IoT), Robotics and Process Automation, Cloud Computing, Social and Mobile. A study done by NASSCOM and BCG identified that these technologies will create around 55 new job roles and will require 155 new skills. This was the situation in 2018. We will see more changes and newer technologies in the coming years. So the curriculum requires to be constantly updated with a periodicity of no more than two years.

2. Teacher Training on Future Technologies: If students are to be equipped with knowledge of the latest technologies, in addition to curriculum updates, we need to train our teachers. Teachers in many educational institutions are not aware of the fast-changing technology and industry landscape. Their exposure and appreciation of new technologies are limited, and as a result, their capability to teach new technologies gets compromised. The only way we can bridge this gap is by continuously training our teachers on newer technologies. Faculty should mandatorily go through refresher programmes and certifications on relevant topics every 3-5 years.

On a related note, we need to ensure that our teachers are well-equipped with the right teaching methodologies. A mere MTech does not qualify a person to become Assistant Professor or a PhD an Associate Professor. MTech or PhD is a good reflection of a person's knowledge, but do not, in any way, imply that he or she has good teaching capabilities. All MTechs and PhDs have to mandatorily undergo teacher training programmes and certified before they can teach in technical institutions.

3. Continuous Reworking on Pedagogy: Teaching methods have to undergo major changes. The traditional method of monologue lecturing is not impactful as students have low attention spans. Distractions from social media and students' ability to source information or learn from online platforms make them even more complacent. We need to find new ways of engaging students through experiential learning.

In IIT Hyderabad, we introduced several new teaching techniques. As opposed to a traditional classroom with rows of seating, we introduced clusters of tables around which students group. With this, we noticed more student participation and learning as opposed to passive listening to teachers' monologues. We introduced the fractal system. We broke down each course into smaller credits. This helped the students choose more credits only if he or she likes the course.This offered the students enormous flexibility to learn what they like. We also introduced flip-classes. What was class work became homework (the student listens to video of the professor in his room / library / playground ahead of the class) and homework became class work (the discussion happens in the classroom). With this model, learning became a lot richer as students now learn not only from the teacher but also from their peers. One size does not fit all and each academic institution needs to discuss and initiate action for contemporary pedagogy while keeping the student at the center of learning. We should continuously look for new ways of engaging the student. For example, using gamification, simulation, and virtual reality will ensure better learning outcomes as they allow experiential learning.

4. Technology-assisted learning: Technology is supplementing student learning. If a student does not understand a concept in the classroom, it is difficult for the teacher to repeat the concept for the benefit of one student. With technology at his disposal, a student can replay the video any number of times or could choose a different teacher's video to learn the same concept. In addition, chat bots are helping students with their questions. Unlike a classroom where time is a limitation, students can ask any number of questions and chat-bots (or robotic process automation tools) can tirelessly prove the answer. MOOCs have to be encouraged, certificates from MOOC platforms need to be recognized, and students should be given credits once they complete the

recognized online courses. This will help in addressing the challenges of shortage of teachers and associated skills.

5. Industry-connect & Apprenticeship Programmes: In the medical profession, a doctor is not certified to practice unless he/she completes an internship for 12 months. While internship / apprenticeship programmes were formulated several years back, academia and industry lagged in their implementation. The processes were draconian with a lot of administrative overhead. There is a major flaw in how we define the role of a graduate engineer. In our country, we believe that a university degree gives knowledge, and polytechnics and ITIs provide the skills to handle real-life situations. This is a myth. We cannot segregate knowledge driven by education and application driven by skills. Even in IT, these cannot be segregated. Concepts such as programming, architecture, database design, etc. are considered as knowledge and programming languages (C++, Python, R, etc.) are considered as skills. No programmer will be useful without a combination of both. It is, therefore, important that we make apprenticeships mandatory. This will help bridge the gap between industry needs and academic deliverables.

The linkages between academia and industry have to deepen. We need to promote faculty and industry expert exchange programmes. This will improve the employability of students. Deeper industry academia interaction will improve the industry's awareness about research, boost their confidence in academia's capabilities, and will encourage them to fund more research projects and monetize them too.We also need industry leaders to participate in the governance of academic institutions. This will help us bridge the gap between academia and industry.

6. Innovation, Incubation, Entrepreneurship: New technologies are opening new opportunities. They are helping us create new products and services. But to realize this potential, we need to promote innovation. In addition to technology skills, we should make sure that our students are taught design thinking, critical thinking, communication skills, collaboration, teamwork, and values. Our ability to encourage students to challenge the status-quo, tolerate failures and learn from failures, be persistent with their ideas, work as teams, and become open to ideas will go a long way in ideation within the student community. Ideas require incubation and mentorship on technology, business, and industry. It is important to groom the students whose ideas can be commercialized as entrepreneurs. Entrepreneurship is an urgent need for our country and technology graduates are the best to seed entrepreneurship

7. R&D Clusters: Research is essential for every nation. Research leads to new ideas and newer ways of executing ideas. Research by faculty will help them deepen their knowledge and guide students in pursuing new technologies effectively. Defining research outcomes is important. Faculty should be motivated to conduct research with measurable outcomes through different monetary schemes and business models. We should encourage the culture of research clusters with a focus on certain technologies.

Let me conclude by saying that while change is imminent and continuous, it also provides enormous opportunities, especially for developing nations such as India. As we equip technical students with 21st century skills such as – Choice (based 'Characteristic of Classroom'), Communication, Collaboration (we are wired to be social creatures), Critical Thinking, and Creativity (a uniquely human skill) - we will bring to industry an innovation-driven and globallycompetent workforce that will fuel India's growth in the coming decades.

Thank you.

BVR Mohan Reddy

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