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Review Article

Grand Challenges for Technical Education in India and The Future of Engineering Education

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Abstract

This Paper provides an analysis of the Challenges and Opportunities for Technical Education, globally and with particular reference to India. The concept of Grand Challenges is first explained, followed by the Grand Challenges for Technical Education in India. The evolution of Engineering Education systems worldwide is traced through the response of Global and National Engineering Education to Industry 5.0. The impact of pervasive Change all around us is demonstrated through several examples, leading to the demise of business and education as usual. The special features of XXI Century Learners and Teachers, the emerging changes in employment and careers and the opportunities and challenges for Engineering Education in India are next discussed. Th evolution of Industry 1.0 to 5.0 is next traced along with the corresponding evolution of Education 1.0 to 5.0. The dire need for changes in Engineering Education Systems and Processes is demonstrated through the changes in the four subsystems comprising the overall system. The future of Engineering Education is postulated in terms of the integration of several features which have existed as separate entities till now, and the creation of Education 5.0 -compatible graduates.

The Concept of Grand Challenges

According to Wikipedia, "Grand challenges are more than ordinary research questions or priorities, they are end results or outcomes that are global in scale; very difficult to accomplish yet offer hope of being ultimately tractable; demand an extensive number of research projects across many technical and non-technical disciplines and accompanied by well-defined metrics." Grand challenges "require coordinated, collaborative, and collective efforts" and must capture "the popular imagination, and thus political support".

In a fourteen-month project, the National Academy of Engineering, (NAE) of the US convened a select, international committee to evaluate ideas on the greatest challenges and opportunities for engineering. The NAE Committee on Engineering's Grand Challenges identified 14 grand challenges and opportunities for engineering during the world's next few generations. It pointed to engineering or scientific research and innovation that look promising for addressing each challenge as well as suggested currently unmet research needs. Follow- up actions have been initiated by several stakeholders, such as Universities by instituting Grand Challenge Scholars, and by Member Academies of CAETS (Council of Academies of Engineering and Technological Sciences), of which Indian National Academy of Engineering is a member.

India inaugurated a Program of **IMPRINT** – **Imp**acting **R**esearch, Innovation and **T**echnology – on November 5, 2015 - highlighting the theme: A Million Challenges, A Billion Minds. IMPRINT identified ten Technology Domains, five each from the Living World and the Materials World.

"Grand Challenges" for Technical Education in India

A review of the several National Education Policies, since Independence, the IIT Review Committee Reports, the National Knowledge

Commission documents, and Reports of the several AICTE Task Forces, and the several Technical Education Conference Proceedings over the years, enables the identification of a set of Grand Challenges for Technical Education in India. They are classified into 11 groups.

National Perspective

- To enhance the GER in Higher and Professional Education from the current 26.3% (2018) to 50% by 2035.

Strategic Planning

- Every institution to define its vision, mission, strategic plan, road map, key result areas and quality policy.

Institutional Culture and Effectiveness

- To promote Innovation and Entrepreneurship among faculty and students.
- To promote inter- and multi- disciplinary teaching and research activities in every institution.
- Every institution to have a culture and ambience of scholarship, quality, excellence, and high morale.
- Every institution to have regular peer review mechanism in place for assessing the effectiveness and efficiency of academic processes.

Leadership Development

- Every institution to have succession plans and leadership development programs.

Teaching-Learning Systems and Processes

- All faculty members to possess pedagogic and communication skills (in addition to domain knowledge), as well as ability to employ Technology-Enhanced Teaching-Learning systems and processes.
- To make T-L processes interactive, feedback-intensive, catering to diverse learners and fulfilling the objectives of Bloom's taxonomy of cognitive competencies.

Research Imperatives

- To double the Ph.D. output in Engineering from the current 1000 to 10,000 in five years.
- To ensure that all faculty members in Higher and Professional Education institutions have Ph.D. qualifications.
- To have all faculty members actively engaged in R&D, in addition to their teaching responsibilities.

Quality Focus

- To ensure that all Higher and Professional Education institutions have up-to-date accreditation by NAAC and NBA to ensure high academic quality.

Faculty and Staff Focus

- Every institution to organize faculty development and staff training programs to keep them functioning at the most up-to-date level of performance and effectiveness.

Student Focus

- To equip all graduates with employability and workplace skills.
- To inculcate professional ethics and social responsibility in all faculty and students.
- To make Teaching an attractive career option for young graduates.

Alumni Focus

- To engage with alumni continuously for eliciting feedback and for resource inputs.

Industry-Academia Collaboration

- To make industry-institute collaboration an important mainstream activity for both partners.
- To ensure reasonable congruence of academic preparation and offerings with overall industry requirements.
- Every institution to engage in sponsored R&D and Consultancy (Industrial and Educational).

Response of Global and National Engineering Education to Industry 5.0

In large measure, Engineering Education follows the developments in Industry and the consequent knowledge and skill requirements of the engineering graduates. Thus, as Industry progresses from Industry 1.0 to Industry 5.0, Engineering Education follows suit from Engineering Education 1.0 to Engineering Education 5.0.

The Impact of Pervasive Change

We are living now in a VUCA world, characterized by Volatility, Uncertainty, Complexity and Ambiguity. At the dawn of the XXI century, many studies have dealt with the need for realigning the Education systems and processes to prepare for the new challenges and opportunities. The whole spectrum of the features of the stakeholders in the Global Engineering Education systems has undergone rapid and major changes during this period, exacerbated by the covid-19 pandemic, which has turned out to be a major game-changer. We are getting used to the new normal, which requires significant adaptations in pedagogy and behaviour.

We are in the middle of exciting changes in almost all aspects of our lives, and the Education sector is no exception. With substantial changes in the nature of inputs to the Engineering Education System, and the job requirements and employer expectations, business-as-usual systems and processes have to give place to novel and innovative ones.

In recent times, Change is the only constant, it is said. The XXI Century is characterized by several distinctive features: We see Change all around us, not only in absolute terms but also in the rate at which it is occurring. Would we have believed about 30 years ago that the following events would actually take place: the unification of Germany, the break-up of the USSR, the lifting of apartheid in South Africa, and the economic reforms in our country? The implications of rapid and accelerating changes have increased uncertainty and lowered predictability.

The Demise of Business as Usual

"The nature and scope of the engineering profession is undergoing dramatic changes, especially in the high-tech areas. Obsolescence has taken a heavy toll on earlier tools, techniques, technologies, and work skills. Obsolete technologies include vacuum tubes, belt-driven lathes, dial-type telephones, spool-type, and cassette tape recorders, records, and record players. Disruptive technologies have yielded substantial improvements. Digital photography has replaced silver halide photographic film, mobile telephony for wireline telephony, hand-held digital appliances for notebook computers, Internet-based sites such as chemdex and e-steel for industrial materials distributors, Internet-enabled distance education for classroom and campus-based instruction, arthroscopic and endoscopic surgery for open surgery, etc"

"Globally, these trends have also affected many technical institutions and they are dramatically influencing the competencies, knowledge, and skills required of engineering graduates. The drawing board and T-square have given way to computer-aided drafting, data acquisition has been automated and digitized, laboratory instruction has changed to model industrial practice, and the content of the various courses largely reflects modern industry".

"There is a pressing need to address two demands: to provide the knowledge, skills, and attitudes that result in the employability of our graduates upon completion of their studies, and to provide an educational foundation that enables our graduates to function effectively and productively in an unfolding future that will be designed by them".

Eleanor Baum (the then) President of ABET made an interesting observation on the changing knowledge and skill demands on engineers: "Engineering students are very good, in the process of the way we educate them, in taking an exam by themselves. The whole system is set up that way, in working a problem alone. But yet in industry, engineering is a *team endeavor*, and skills of working in a team environment are things that are not easy to acquire, and engineering schools were doing very little in this regard".

XXI Century Learners and Teachers

The XXI century Learners represent a new breed: They have not touched a typewriter, played a record album, calculated with a slide rule, travelled in a steam engine, hand-written a letter, or known a world without computers and internet. Today's school-age generation knows a lot more about Technology than their teachers. Young kids get bored if they are doing only one function at a time; they need multiple stimuli.

These learners have some unreasonable expectations, however: that learning is easy and requires no effort; access to information is the same as acquisition of knowledge; acquisition of knowledge and skills can make up for the need for experience; and success in life and work requires no hard work or commitment.

The emerging trends impose new demands on the Teachers. The whole notion of the Teacher as disseminator of knowledge is now turned on its head. While in the old scenario, the teacher was the boss, in the new scenario, the teacher becomes the facilitator, coach or mentor. "The teacher is no longer the sage on the stage, but the guide on the side". She is becoming less central to the learning process. Will Information Technology, like what we thought of Educational Technology a few decades ago, replace the teachers and make them superfluous? As a wag said: "Any teacher who can be replaced by a machine deserves to be replaced".

Changes in Employment and Careers

We are already witnessing major changes in the nature of employment, work, jobs and careers. It is predicted that "less than half the workforce in the industrial world would be holding conventional full-time jobs. More and more people will be self-employed; many will work temporary or part-time, sometimes because that is the way they want it, and sometimes because that is all that is available".

The patterns of working life are changing, The Economist noted, as evidenced by anecdotal changes, such as: more frequent job changes, more freelancing, more working at home, more opportunity but also more uncertainty. McKinsey has warned its clients that the most important challenge for companies is "the War for Talent".

Icarian, a Silicon Valley firm, applied "just-in-time" manufacturing techniques to employment. At very short notice, it could summon not just secretaries and assistants, but free-lance engineers, technical writers, marketing directors and even chief executives (at hourly rates!).

Some American employers are offering an implicit (and sometimes explicit) deal to their employees. "Accept that we may have to sack you; and in exchange, we will make sure that you have marketable skills needed to find another job".

Employers are increasingly attaching importance to Attitude, Emotional Intelligence and Work Ethics. A Harvard University study found that when a person gets a job, 85% of the time it is because of the attitude; and only 15% of the time because of how smart they are, and how many facts and figures they know.

Opportunities and Challenges for Engineering Education in India

The Engineering Education system in India has several distinctive features --- such as huge size; considerable diversity of many types; several strengths and weaknesses; several policy pronouncements; several pending Bills; a small number of institutions of quality in a sea of mediocrity; the emergence of the private sector as a major player; etc.

There are several national policy initiatives for laying down the roadmap for the future, such as the National Policy on Education 1986, revised in 1992; the Science Policy Resolution, The Technology Policy Statement, The Science and Technology Policy, The Science, Technology and Innovation Policy; different Plan Documents; National Knowledge Commission Recommendations; Yash Pal Committee Recommendations; National Higher Education Policy (RUSA) etc. These are the emerging *Opportunities* for Change – for the better.

The *Challenges* have long been recognized, and the proposed changes address these challenges. The challenges include: lack of appropriate institutional governance structures and mechanisms; inadequate numbers and quality of faculty members and PhDs in engineering; lack of academic leadership; inadequate quantity and quality of research; lack of employability skills of graduates; insufficient industry-institution collaboration; inadequate capacity of the National Board of Accreditation (NBA) to accredit the large number of engineering programs in the country; none of our institutions figuring in the global ranking lists; uncertainty in the regulatory environment; several institutions lacking academic autonomy and preponderance of affiliated institutions; difficulties in placement of post-graduates; lack of design and innovation capabilities; etc'.

A new *National Education Policy* has been announced recently. It envisions an "India-centered education system, that contributes directly to transforming our nation sustainably, into an equitable and vibrant knowledge society, by providing high quality education to all".

Its major policy Recommendations and major Reforms in the sphere of Higher Education and Research are:

Achieve a Gross Enrolment Ratio of 50 % by 2035; Holistic and Multidisciplinary Education ; Multiple Entry / Exit options to be introduced; M.Phil. to be discontinued; Credit Transfer and Academic Bank of Credits; Higher Education Institutions (HEIs) classified into Research Intensive/Teaching Intensive Universities and Autonomous Degree Granting Colleges; Model Multidisciplinary Education and Research University (MERU) (in or near every District); Graded Autonomy : Academic, Administrative & Financial; Phasing out Affiliation System in 15 years; National Mission on Mentoring; Independent Board of Governors (BoG); Single Regulator for Higher Education (excluding Legal and Medical); On-line Self Disclosure based Transparent System for Approvals in place of 'Inspections'; Private Philanthropic Partnership ; Public Investment in Education Sector to reach 6% of GDP at the earliest; National Research Foundation (NRF) to be established; Internationalisation of Education to be encouraged; Integration of Vocational, Teacher and Professional Education; Standalone HEIs and Professional Education Institutions to evolve into Multidisciplinary Institutions; National Institute for Pali, Persian and Prakrit; establishment of National Educational Technology Forum (NETF); and Ministry of Human Resource Development (MHRD) to be renamed as Ministry of Education.

It is proposed that the Preparation of Professionals must involve an education in ethics and importance of public purpose, an education in the discipline, and an education for practice. It must centrally involve critical and interdisciplinary thinking, discussion, debate, research, and innovation. For this to be achieved, professional education should not take place in the isolation of one's specialty. Professional education thus becomes an integral part of the overall higher education system. Stand-alone agricultural universities, legal universities, health science universities, technical universities, and stand-alone institutions in other fields, shall aim to become multidisciplinary institutions offering holistic and multidisciplinary education.

Specific recommendations have been made relating to Online and Digital Education: Ensuring Equitable Use of Technology: "The recent rise in epidemics and pandemics necessitates that we are ready with alternative modes of quality education whenever and wherever traditional and in-person modes of education are not possible. In this regard, the National Education Policy 2020 recognizes the importance of leveraging the advantages of technology while acknowledging its potential risks and dangers. It calls for carefully designed and appropriately scaled pilot studies to determine how the benefits of online/digital education can be reaped while addressing or mitigating the downsides. In the meantime, the existing digital platforms and ongoing ICT-based educational initiatives must be optimized and expanded to meet the current and future challenges in providing quality education for all"

Addressing the digital divide: "Given the fact that there still persists a substantial section of the population whose digital access is highly limited, the existing mass media, such as television, radio, and community radio will be extensively used for telecast and broadcasts. Such educational programs will be made available 24/7 in different languages (22 official languages) to cater to the varying needs of the student population. A special focus on content in all Indian languages will be emphasized and required; digital content will need to reach the teachers and students in their medium of instruction as far as possible".

In this age of globalization and the interdependence of the nations of the world in the economy, industry and education sectors, our systems, processes, and policies need to be released from the constraints of the status quo mindset. We need radical transformations, not incremental ones. In a system as diverse and heterogeneous as ours, what we can hope for is the creation of expanding islands of excellence that ultimately pervade the whole system.

Evolution of Industry 1.0 To 5.0

The history of Industry 4.0 tracks the manufacturing industry from the industrial revolution to the recent digital revolution and beyond. Industry 1.0 or the first Industrial Revolution began around 1760 involving the transition to new manufacturing processes employing water and steam. "During the 1st IR, water and steam were used to mechanize production. During the 2nd IR, electric power was used to create mass production. During the 3rd IR, electronics, and information technology were used to automate production. The 4th IR is beyond an enhancement of the 3rd IR, in which the advancement of new technologies blurs the lines between the physical, digital and biological worlds." The new technologies evolve at exponential pace and there is no historical precedent that marked the beginning of the evolution, hence being called disruptive technologies. These advancements are led by the emergence of artificial intelligence, robotics, the internet of things, autonomous vehicles, bio and nanotechnology, 3-D printing, material science, quantum computing and energy storage. The IR 4.0 affects not only the business, governance and the people, it also affects education as well, thus the name Education 4.0 came into existence.

Industry 4.0 was started by a German Government memo released in 2013, where the term "Industrie 4.0" was first mentioned. It outlined a plan to almost computerize manufacturing industry fully without the need for human intervention. Industry 4.0 is a label given to the combination of traditional manufacturing and industrial practices with the digital world encompassing us. The initial goals in Industry 4.0 were automation, manufacturing process improvement, and production optimization. The "Industry 4.0" definition is not the same everywhere. It goes beyond the factory and is more than automation and data exchange. The cyber-physical systems revolution is summarized as the Fourth Industrial Revolution and is fundamentally changing the way we live, work, and relate to one another.

There is another term iIoT which is used synonymously with IoT but is slightly different; Industry 4.0 focuses primarily on the manufacturing sector, whereas iIoT covers all sectors where industrial / professional equipment is used.

We are now talking about Industry 5.0 which is about using the latest tech to not only customize but also to personalize the products (and production processes). "The focus lies on applications where the personalized touch delivers a better customer experience, which brings an additional value (and revenues)".

Skobelev and Borovik point out that the more exact term instead of Industry 5.0 is "Society 5.0" (SuperSmart Society) that was introduced in 2016 in Japan. "Unlike the concept of Industry 4.0, Society 5.0 is not restricted only to the manufacturing sector, but it solves social problems with the help of integration of physical and virtual spaces". They also point out that in 2013 Cisco offered the term "Internet of Everything" (IoE), which is considered to be wider than IoT". According to Cisco IoE is" the networked connection of people, data, processes and things".

Evolution of Education 5.0

Education 5.0 is the culmination of a series of stages of recognizable features of the design and development of educational content and delivery and seems to follow in the footsteps of Industry or Industrial Revolution (IR) 5.0.

It is interesting to work backwards and look at the features of and Education 1.0 to 5.0 – and whether to characterize this as an evolution or a revolution driven by the advancement of technology along with the changes in student and industry needs.

Education 1.0 is considered to be a teacher-cantered system in which the teacher dispenses knowledge in the classroom and the student is a passive recipient, and very little Technology is employed in the classroom.

Education 2.0 is an Exam-based approach, involving in a large measure, memorization of knowledge, and the focus shifting from Teaching to Learning and learning outcomes, with Technology beginning to enter the educational process, but 'uncoordinated technology correlation with the curriculum', and the students better at harvesting technology than the teachers.

Education 3.0 involves a student-cantered approach, in which the teacher is transformed into a coordinator, facilitator, coach, adviser, guide, extensive use of technology and the student becomes responsible for his/her learning, and lesson plans are now called learning plans.

Education 4.0 is a response to the needs of IR 4.0 where human and technology are aligned to enable new possibilities. In Education 4.0, Peers become very significant in their learning. They learn together and from each other, while the teachers assume the role of facilitators in their learning.

Education 4.0 includes flipped classroom mode of student learning, wherein self-learning occurs at home or outside college, while in the classroom students receive face-to-face instruction and are provided with clarifications and participate in peer to peer and group learning. Technology is pervasive in this mode, both for instruction and assessment. In this mode Educators are better prepared to address challenges of preparing learners for "jobs that don't yet exist, using technologies that have not yet been invented". It is predicted that "about two-thirds of children entering primary schools today will ultimately work in new jobs and functions that currently do not exist; and nearly 50% of the subject knowledge acquired during the first year of a four-year technical degree will be outdated by the time the students graduate". The core of the undergraduate programs involves the learning of STEAM subjects: Science-Technology-Engineering-Arts-Mathematics.

"Education 5.0 focuses on Innovation and Industrialisation, Higher and Tertiary Education, Science and Technology, and towards problem-solving and value creation."

In Education 5.0@UiTM, Malaysia "flexible and adaptive learning paths, focus on imparting life /transversal skills, student centric learning methods and incessant use of technology are deeply embedded with values and principles". Education 5.0 @UiTM is about "eradicating complacency, discarding lethargy, emphasizing 'business unusual' and doing the right things in a swift and sure way". Education 5.0@UiTM is defined as a "learning - centric ecosystem that is sustainable, balanced and principled, driven by values, powered by intellect and afforded by new, ubiquitous technologies". It is "not about smart technology and the machine's capability to do what humans do; rather it is about what humans can do well rendered by smart technology and machines".

Need for Changes in Engineering Education Systems and Processes

In considering the global and Indian context for engineering education reform, it is helpful to think in terms of four essential subsystems which have a major influence on the design and effectiveness of an "engineering system": inputs, output requirements, environment and ambience, and strategic goals.

Inputs

Students (twenty-first century learners) entering our engineering institutions are very technology-savvy, need multiple stimuli, have a low tolerance for static content and monotony, and look for instant gratification. They believe that learning is easy and requires no effort, access to information is the same as acquisition of knowledge, acquisition of knowledge and skills can make up for lack of experience, and success and prosperity require no hard work. Today's students are used to TV remote controls, computer games and Web browsers, all of which allow them to switch content at will. Their short attention spans, lowered tolerance for boredom, and aversion to static media, all challenge educators to provide information in dynamic, compelling, and interactive ways.

Output Requirements

The twenty-first century attributes of graduating engineers include the pursuit of life-long learning, ability to acquire knowledge from neighbouring disciplines, ability to work in teams, exposure to commercial disciplines, creativity and innovation, integrative skills, international outlook, ability to employ IT, ability to work at the interfaces between traditional disciplines, and a commitment to sustainable development. The recent U.S. National Academy of Engineering report, *The Engineer of 2020*, states it well: future engineers will need to "…have the ingenuity of Lillian Gilbreth (the Mother of Ergonomics), the problem-solving capabilities of Gordon Moore, the scientific insight of Albert Einstein, the creativity of Pablo Picasso, the determination of the Wright brothers, the leadership capabilities of Bill Gates, the conscience of Eleanor Roosevelt, the vision of Martin Luther King, and the curiosity and wonder of our grandchildren."

Environment and Ambience

The twenty-first century is characterized by a significant impact of technology on education, industry, commerce, lifestyle, entertainment and society, the emergence of a knowledge industry and economy, the demand for mass education, the widening of disparities among countries and regions as characterized by the technology divide, digital divide, education divide, and prosperity divide, the increased uncertainty and lowered predictability from accelerating change, the potential of ET and ICT for enhancing the effectiveness of learning, changing employer-employee loyalty relationships, globalization, and the international market economy, and an emphasis on continuous professional development. The future employment for engineers will be characterized by a fall in full-time employment, obsolescence of knowledge and skills, changes in job requirements, ICT-enabled manufacture, and services, domestic as well as foreign employment, offshore employment, etc. And this employment will take place in a changing engineering profession driven by environmental considerations, customization, sophisticated diagnostic and computational tools, a wide choice of materials, and innovation as the basis of global competitiveness.

The Future of Engineering Education

The XXI Century Paradigm for Engineering Education must incorporate the integration of several features which have existed as separate entities till now : initial education plus continuing life-long education; institutional component plus industry component; formal education plus non/in – formal education; education plus training; quantitative expansion plus quality assurance; technology plus management; traditional instruction plus web-based instruction; print media plus electronic media; traditional libraries plus digital libraries; educational technology plus information technology; traditional education plus distance education; and , last but not the least, teaching plus learning.

In essence, XXI Century Engineering is: a multi-disciplinary, multi-mode, multi-media, multiple-partner Enterprise.

As far as the creation of Education 5.0 -compatible graduates are concerned it is widely recommended that they should be T- or pi-type of professionals, combining depth in one discipline and breadth in one or two areas, such as from liberal arts.

References

1. Natarajan R. An Indian Perspective on Engineering Education Reform, Guest Editorial, J Engineering Education (2008): 1-2.
2. Ministry of Human Resource Development, Government of India, National Education Policy (2020).
3. Petr Fisk. Changing the Game of Education.
4. Amon Murwira. "Education 5.0 a catalyst for achieving Vision 2030". The Herald (2020).
5. UiTM Academic Compass: Navigating the Future, EDUCATION 5.0@UiTM (2019).
6. BY Takamitsu Sawa. Reforming education for Society 5.0, the Japan Times (2019).

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