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Innovation-centric Teaching and Learning Processes in Technical Education

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Abstract: Globalization has put countries in competitive and collaborative mode. Underdeveloped nations are in catch-up phase, developing nations are in competitive phase and the advanced nations are in commanding phase with respect to certain technologies. Innovation — Technological, Business and Education — is imperative for sustainable socio-economic development. Education innovation is basis for technological and business innovation. With the advent of Information and Communication Technologies (ICT), curricula, mode of instruction and teaching — learning methods are undergoing major revision. There is attitudinal mismatch between digital native learners and digital immigrant teachers. Engineering education needs revisiting curricula and pedagogy. *Knowledge* acquisition, guided/unguided, *skill* development, simulated/hands-on, and *concern* about society are part of Teaching-Learning processes. Innovation-centric education radar is presented that relates four key dimensions: Offerings (What), Beneficiaries (WHO), Processes (How), and Presence (Where)

Assessment and accreditation bodies in various countries for higher technical education place high weightage for Teaching–Learning processes. Innovation needs to be fostered among students and teachers during Teaching–Learning (T-L) processes. Inclusive innovation that may comprise laboratory based structured innovation and Jugaad/unstructured intuitive innovation needs to be promoted for rapid inclusive growth. Bridging Vocational training with engineering education is also advocated to meet huge demand of quality technicians and engineers with entrepreneurial traits. Inclusive innovation will accelerate inclusive growth of the country. Steps to augment innovation may include curricular reforms, faculty development, prolonged academic leadership, accreditation renewal on higher standards, innovation-conducive pedagogy, adopting a village for overall growth, professional communication.

Key words: inclusive innovation, jugaad, innovation index, competencies, assessment of engineering education

1. Innovation for Sustainable Development

Innovation enabled human beings to transform their Society from Tribal to Agrarian to Industrial to emerging Knowledge-based society.

1.1 Novelty in Concepts to Construct

What's innovation? The related concept terms are creativity, innovation, jugaad, invention, discovery, and entrepreneurship.

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- Creativity involves generating new ideas or concepts.
- Innovation is successful implementation of creative/novel ideas in specific context having impact on economy and society. Innovation may be linked to improvements in efficiency, productivity, quality, competitive positioning, etc.
- Invention is finding or constructing something new out of box.
- Discovery is finding something new in the nature.
- Jugaad may connote to innovation that may not readily be explained in structured manner. Such innovation may be done even by untrained workers.
- Entrepreneurship is the ability to exploit change as opportunity to create new business/service. Successful entrepreneur aims at high and tries to create value to convert material into “resources”.

What’s jugaad? Jugaad is a new term for unstructured or intuitive innovation. It is an Indian term for successful implementation of creative thoughts to improve productivity, quality, efficiency, etc. This is often done by semi-skilled workers. They base on intuitive approach rather than adopting well formed procedures. Preparing automobile parts, repairing mobiles and electric gadgets are some examples of jugaad. But every act of getting acceptable product/service/solution will have a set of well formed procedures. Jugaad is viewed as specialized skill owned as implicit knowledge. Conversion of implicit innovation (jugaad) into explicit innovation is doable task and it will add to economy. It will also open up avenues for identifying requisite skills and organizing training programs for skills development.

How will innovation have impact on the society?

Globalization has broken walls to cross borders. This will propel cultures to mingle to set into equilibrium. Innovation is a characteristic of communities that brings them in the forefront of technological advancements with economic gains resulting into better quality of life. Countries with higher innovation index progress on the path of sustainable development. They are often givers rather than borrowers. They export more than import. It is innovation of walkman that made Sony popular. Innovation of iPad/iPhone swang market share towards Apple products. Of course associated with technological innovations, there is need for innovation in business practices as well. We may study innovation index of various countries and look for requisite factors that subscribe to increase innovation.

1.2 Global Innovation Index

Global innovation index gives an overall innovation index with innovation inputs (i.i) and innovation output (i.o). This is as per the report that was produced in March 2009 jointly by the Boston Consulting Group, the National Association of Manufacturers and the Manufacturing Institute. The typical country-wise rankings with overall innovation index, innovation inputs (i.i) and innovation output (i.o) are given below.

Innovation inputs included fiscal policy, education and innovation environment. Innovation outputs included technological performance such as patents, technology transfer and other R&D results; business performance such as labor productivity and shareholders’ return; and impact of innovation on business migration and economic growth (Table 1).

These indicators may not give real picture, however they indicate some correlation between innovation input-output and overall innovation index. Emerging economies, china and India, have large population and huge market potential, Innovation that have impact on nation’s economy may depend on Technological innovation in terms of products and processes, Business innovation in terms of business process reengineering, and Education innovation in terms of innovation-centric education and training. Educational innovation is basic that prepares ground for Technology and Business innovations.

Table 1 Innovation Ranking of Some Countries — Small And Large (Mixed)

Rank	Country	Overall index	Innov. inputs	Innov. outputs
1	Singapore	2.45	2.74	1.92
2	South Korea	2.26	1.75	2.55
3	Switzerland	2.23	1.51	2.74
7	Finland	1.87	1.76	1.81
8	USA	1.80	1.28	1.16
9	Japan	1.79	1.16	2.25
12	Netherlands	1.55	1.40	1.55
15	UK	1.42	1.33	1.37
16	Israel	1.36	1.26	1.35
18	Germany	1.12	1.05	1.09
20	France	1.12	1.17	0.96
22	Australia	1.02	0.89	1.05
27	China	0.73	0.07	1.32
38	Italy	0.21	0.16	0.24
46	India	0.06	0.14	-0.02

2. Technical Education in 21st Century

In the emerging knowledge based society, there is explosion of information, easy access to multimodal information with a variety of analysis tools, educational expectations are not what learnt but problem solving abilities — critical thinking, analytic abilities and soft skills.

What are the obstacles? Distractions, abundance of information, imbalance in curricula, stereotyped evaluation methods are a few obstacle often cited. Net savvy students often bunk the classes. Copying the assignments is their collaborative venture. At the time of placement industry finds students weak in basic science concepts and poor in communication. Typical observations are made as follows:

- Weak in basic sciences — Physics, Mathematics and Chemistry.
- Basic concepts of core engineering science subjects are not clear.
- Terminology remains as bundle of jargons. Semantic aspects of engineering terminology are not clear.
- Poor (English) communication skills.
- Sensitivity to society is very low. Interaction with masses is absent. There is no mini project in local language.
- Multilingual computing is not introduced.
- Focus on R&D is minimal.
- Use of open technologies/standards is not encouraged.
- Teaching-Learning processes are not innovation-centric.
- Interest for higher education or entrepreneurship is lacking.

2.1 Attitudinal Mismatch

The dawn of 21st century witnessed phenomenal growth of ICT. Computational power increased, Price got reduced and Size shrank on and on. Kids have easy access to information, kids play with computer, learn while gaming, expose to vast spatial and temporal variations in history, economy and ecosystem. Kids learn fast how to learn a new piece of equipment, package or event-maker. But parents and teachers are brought up and trained over two-three decades back when ICT was just emerging. There is conceptual and practical mismatch in the attitudes of teachers and learners. The conflicting teaching-learning approaches co-exist. Teachers find easy to go by the traditional learning media and "chalk-talk-test" teaching approach. Learners are Net-savvy. We may call them Net-gens who prefer to know "Where to access information" rather to know "how does it work". They like dynamic media rather than static text and diagrams.

Research in Neurobiology shows that the exposition of digital technology is rapidly altering our brains — new neural pathways are constructed in brain, old ones weaken. With the advent of Information Technology, brains of users — Learners — are evolving at a speed like never before. Howe and Strauss (2007) details seven core traits of New-Gen.

Teaching Institutions should respond accordingly (Table 2).

Table 2 Teaching Institutions' Response

Special	-	Parents think their child is special. Institution should be able to "protect and educate".
Sheltered	-	Security and safety is prime concern.
Confident	-	Excited about future.
Team-Oriented	-	Peer pressure may be a good thing
Conventional	-	"Believe in big brands" and "go with the group". "Originality" may be disturbing to New-gens.
Pressured	-	Worry for grades.
Achieving	-	Want strong community life.

Thus, ICT use separates two generations — "Digital Natives" and "Digital Immigrants". Kids are digital users of the digital technology — computers, video games and internet. They prefer multimedia information. Teachers are Digital immigrants who learn to adapt to digital environment. They speak out outdated pre-digital age language, but try to teach those who speak an entirely new (digital) language. A survey by Ivanova (2009) reveals that 48% remember information when they have live experience; 85% study by experience how to operate a new device; and interestingly 67% are seeking thorough and lasting knowledge. Teens are Web 2.0 literate. 100% use video sharing, 81% peer-to-peer networking, and 67% use social media. Teens still have critical thinking, long-term planning skills and seek to get lasting knowledge. Net–Gens don't think in terms of technology, they think in terms of the activity technology enables. To them, interest is on access tool. We need to focus on the technology use to increase customization, convenience, connectivity and collaboration of students.

2.2 Pedagogical Approaches

There is lot of literature discussing innovation in a company, firm or organization. Innovation requires critical and systems thinking, cognitive dissonance by recognizing inadequacies and constructivist approach of creating new ideas with learning from experiences. Innovation management is upcoming area. But the root of mind-set buildup for innovation lies in education in schools, colleges, institutions and universities. Reforms in curricula and teaching-learning processes (Om Vikas, 2010) are often suggested.

Sanjay Goel (2010) in his PhD thesis discusses many such issues especially with reference to Software Development Education. Instructional interventions, framework of pedagogic engagements, cognitive dissonance, systems approach, constructivism approach, critical thinking skills, etc are discussed in the context of learning.

Vijay Vaishnavi et al., outlines a multi-dimensional framework to formalize the characteristics of teacher (who), students (whom), topic (what), objectives (why); and decisions involved in employing problem based learning (PBL). Next generation systems would require not only knowledge (technical, design) and skills (teamwork, organizational, multi-user dealing), but also knowledge of standards and skills to deal with cross-functional business processes and to manage potential conflicts among stakeholders. PBL compromises between two different learning theories — constructivist learning theory that argues that forms own abstract concepts, and situated learning theory that argues that students engage in a "community of practice" and learn in context/situation. In PBL, situation is placed prior to the concepts needed to get answer.

As complexity of problem increases systems development and integration are emphasized. A concept may be an object, process or relation. Tightly coupled interconnected concepts form a "system". Loosely coupled systems may form "system of system". This gives rise to the need of system integration skills.

2.3 Imbalance in Curricula

IIT Kanpur report (S. S. Prabhu, 2000) on engineering curricula review discusses findings of 1st Review (1970–1972), 2nd Review (1979–1981), and 3rd Review (1990–1992). Until 1980 the duration of the BTech program was 5 years. From 1981 onwards the duration of B Tech Program was reduced to 4 years. This affected the proportion of the Humanities & Social sciences (~20%), Maths & Basic Sciences (~25%), Engineering sciences (~25%), Engg Analysis & Design (~25%), and Electives (~10%) with respective reduction in Maths & Basic Sciences to ~40%, and HSS to ~37%. Four elective streams were identified with core and soft core electives. Most of the professional courses were retained. In 5-year BTech program, there were 8–10 HSS courses making up to 16%–19% of the curriculum, this got reduced to 4–5 HSS courses that is about 10%–11% of the 4-year BTech curriculum. It is to notice that a good HSS content is necessary for a well-rounded engineering education. Another anomaly is noticed in time and weight proportion of Lecture, Tutorial and Practical. Lecture content is on higher side. Further attraction to hard core engineering disciplines is proving difficult in the wake of emerging Information Technology. New courses are being suggested and there is emphasis on professional and communication skills, and life-long learning. It is felt that the curriculum be broad based and flexible.

We need to revisit duration and curricular content of Engineering Graduate program. We may perhaps promote 5-year integrated program in Engineering and Innovation Management. Therein appropriate HSS courses and professional communicative skills may be added without sacrificing professional courses. Innovative approaches need to be adopted in Teaching-Learning processes such as introduction of puzzles to motivate students, case studies, team projects and neighborhood problem solving. Open innovation is encouraged in educational institutions.

3. Skill Proficiency Spectrum

Countries labor force in (20–24) years age undergone the formal vocational training: India (5%), Mexico (28%), Industrialized nations (60%–80%), Korea (96%). China has 500,000 senior higher secondary vocational schools, whereas India has about 5,100 ITIs and 600 VET schools.

India's tremendous potential is demographic dividend. Working age population will be 63% by 2016.

There is wide spectrum of skill development starting from certificate to diploma and degree level programs.

3.1 Issues Relating to VET

Challenges to address in the case of VET(Vocational Education & Training) include:

- Disconnect with supply and demand of skills

- Curricula lag behind the need of industry
- Poor quality of vocational training
- Lack vertical mobility and transfer of credit..
- Low prestige attached to vocational training
- Vocational training and vocational education are dealt with separately
- Lack enterprise skills in all VET programs
- Poor communication skills

In developing nations, there are often separate Government departments/ministries to plan and promote vocational training, vocational education and engineering education respectively. Vocational training remains specific and terminal program. This is opted upon failure in getting admission in engineering education. Students from economically poor families also opt for vocational training. In the case of vocational training, admissions are easy to get at even lower grade ranks, fee is low, most of institutions are supported by government, and competitive environment is missing. The intake is disheartened. This is nation-wide psyche about vocational training. Whereas in the case of engineering education admission is tough, fee is high, job prospects are lucrative to get white color jobs, there is potential to rise early in management cadre, there is regular check on quality of education. Large number of institutions is in private sector that creates a competitive environment.

Intake to vocational training is largely Right brain predominant who would be good in doing things by hand, and good in creativity. Intake to engineering education would be more towards Left brain predominance that is they would be good in analysis, logic, and design. Society would benefit of the cohesive mix of both of these.

Trainability is human characteristic. It is, therefore, proposed to connect up these programs with optimism having supposition that *"skill precedes knowledge"*. That means, upon acquiring practical skills one would be inquisitive to know science behind such practical projects/applications. We need to device bridge course to bring up the vocational training pass-outs to be worthy of getting into engineering discipline. They would be inquisitive of learning science in vocation. Their presence would improve overall practical aspects in laboratories through peer-interaction.

3.2 Issues Relating to Engineering Education

- Engineering Education is disjoint from Vocational Training (VT)
- There is no direct vertical mobility in the case of vocational training. Of course they may first get into 2nd year of Polytechnic (3-years program) and the Polytechnic pass outs in 2nd year of B.Tech (4-years program).
- Engineering graduates lack aptitude for practical aspects of building, commissioning and testing things.
- HSS (Humanities and Social Science) content in the Engineering curricula is low.
- Teaching-Learning processes normally don't emphasize on innovation, exploratory learning and constructivist approach.
- Sensitivity towards "relevance to society" remains dismal low.
- There is emphasis more on Lectures (theory) and less on Practicals.

Industry is not much enthusiastic to impart industrial training/internship for less than 6 months. Industry likes to get trainees on regular basis so as not to disturb their normal pipeline activities rather to augment this.

3.3 Bridging Vocational Training and Engineering Education

- Vertical mobility from ITI level Vocational Training to degree level BTech Program in Engineering Education will, in the long run, improve practical proficiency and Quality of products, processes and services consequent upon the hypothesis : “*Skill precedes knowledge*”.

- How to do it? Bridge Course of 2 Semesters is suggested:

Sem1: 1. Basics-I of Physics, Chemistry, Mathematics
2. Communicative skills (English)
3. Quality & Standards
4. Vocation-specific Group Project

Sem2: 1. Basics-II of Engineering Physics & Engineering Maths
2. Communicative English
3. Science in Vocation (case-study based)
4. Interdisciplinary Vocational Group Project

3.4 Evaluation Methods

Evaluation is aimed at testing efficacy in building knowledge, skill and attitude in Cognitive, Psychomotor and Affective domains respectively. Traditionally cognitive tests are carried out in classroom and skill tests in the laboratory. Attitude is viewed as habit in the long run. It is desirable to test the concepts and co-related concepts and problem solving ability. Surprise quizzes, open book quizzes, time-bound team exercises, and collaborative projects may be more effective. Peer-evaluation will be motivational and make them more responsible. Evaluation should NOT be designed to test their deficiencies and weaknesses. Evaluation must eventually result into positive learning and confidence. Evaluation needs to be embedded in the teaching-learning process. Continuous and Comprehensive Evaluation may include 2–3 formative tests and a summative test. Innovation may be considered additional ability to be encouraged. Puzzles, group discussions and team projects may excite them to think innovatively.

3.5 Engineering Education Training: To Groom up Academic Leaders

Currently, fresh B.Tech start teaching at B.Tech level, fresh M.Tech at M.Tech level due to paucity of manpower. There is no program equivalent to Bachelor/Master in Education for engineering graduates. The modular (trimesters) Program is suggested for orientation of fresh engineering graduate teachers. The content covered will include

- Basic Concepts of Sciences: Physics, Chemistry, Mathematics 25%
- Core Concepts of Engineering Science(case-study based) 25%
- Teaching-Learning Processes/Pedagogy 20%
- Professional Communicative Skills 10%
- Managerial Skills 10%
- Life Management & Ethics in Engineering 5%
- Project: High Tech solution in Low-Tech Environment. 5%

4. Innovation-centric Education Radar (Figure 1)

Innovation may be viewed as multi-dimensional activity (M. Sawhney, R. C. Wolcott & Indigo Arroniz, 2007). We may broadly consider four key dimensions: (1) Offerings: product/services (what), (2) Beneficiaries: users it serves (who), (3) Processes: it employs (How), (4) Presence (Where).

Successful innovation strategies tend to focus on a few high-impact dimensions rather than attempting many dimensions at once (Table 3).

Table 3 Innovation–centric Education Radar: A 360-Degree View (Om Vikas, 2010)

S/No.	**Dimension**	**Definition**	**Remark**
1	Offerings (**What**)	Develop innovative new products or services or Human Resource in emerging areas of technology.	Develop and scale up intake in UG, PG and doctoral programs in emerging inter-disciplinary areas.
2	Platform	Use common components or building blocks to create derivative offerings.	Develop specialised modular training programs in thrust areas of national relevance.
3	Solutions	Create integrated and customized offerings that provide end-to-end solutions.	Integrate domain-specific specialised programs into PG degree programs. R&D to provide High-Tech solutions in Low-Tech(rural) environment. Integrate higher technical education with vocational education
4	Beneficiaries (**Who**)	Discover unmet user needs or identify underserved user segments.	Attract talent to work in Advanced emerging areas. E-skills certification of specific skills of various levels
5	Stakeholders' Feedback	Redesign user interactions across all touch points and all moments of contact.	Revisit Curriculum, pedagogy and projects in collaboration with industry in view of rapid technological advancements.
6	Value Capture	Redefine how organization/institution creates innovative new revenue streams.	Develop project proposals for sponsored research and consultancy. Organise e-skills testing and certification.
7	Processes (**How**)	Redesign core operating processes and integrate with other processes to improve efficiency and effectiveness.	Establish innovation-centric teaching-learning processes integrated with R&D projects and visits to other centres, research groups and industry. Effectively integrating ICT aids, e-learning resources and peer/collaborative learning in teaching-learning processes.
8	Organization	Change form, function or activity scope of the organization. Recognize the change imperative.	Evolve transitional integration from applied R&D to enhanced Research and academics in futuristic areas.
9	Supply Chain	Think differently about faculty, knowledge sourcing and fulfilment. Inspire to innovate out of box and learn from initial innovations.	Attract talent from industry to meet demand for industrial innovation. Closure interaction with industry. Inspire to innovate out of box. Get skilled intake from vocational streams.
10	Presence (**Where**)	Create new distribution channels or innovative points of presence, including the places where offerings have demand.	Create Extension Study & Training Centres webinars etc to reach the unreached in far off places.
11	Networking	Create network-centric intelligent and Integrated offerings.	Effective knowledge collaboration within the organization and with premier institutions/NGOs, R&D labs and industry
12	Brand	Leverage a brand into new domains.	Lateral business innovation using brand name for novelty and user friendliness. Startups in incubators.

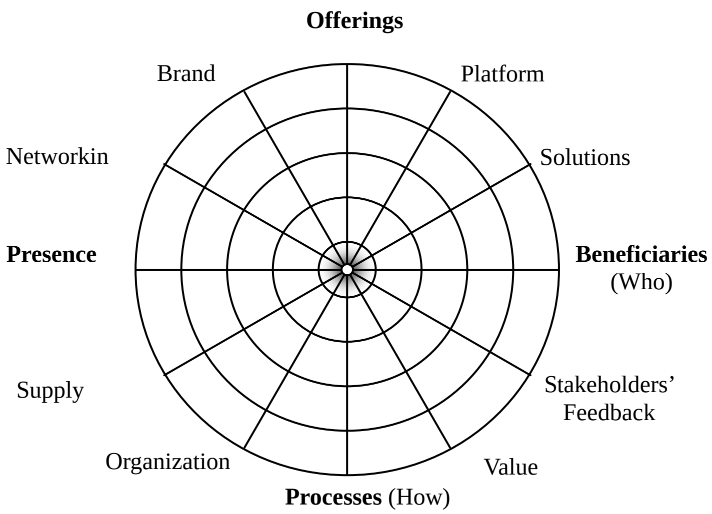

Figure 1 Innovation-centric Education Radar

Innovation may be categorized as Closed Innovation and Open Innovation based on the policy whether ideas remain constrained within the organization or even shared externally. Henry Chesborough (2006) defines Open Innovation as the use of purposive inflows and outflows of knowledge to accelerate internal innovation. Open innovation however explicitly incorporates business model as the source of both value creation and value capture. Open innovation model promotes technology in-sourcing and also creates IP intermediaries for licensing new ideas and exploring new markets for spin-off technology.

Innovation in an organization may be leader-driven or learning process-driven. Rules and procedures, and old mind-set are obstacles in innovation. To invent is not to rule. Escape from the current business model. Encourage change. Remember to forget.

Robert Chapman Wood (2007) discusses Strategic Innovation as development of new business models and effective introduction of dramatic innovations to the market place. Five leadership steps that support innovation success in an organization involve recognition/fear of crisis, a vague but potent goal, initial innovation experiments, and continuous learning from them to bring effective strategy innovation routines into existence.

5. Assessment and Accreditation of Technical Education

There are a number of Accreditation boards in various countries such as USA, UK, Australia, Japan, India etc.

5.1 Expected Competencies

Common competencies expected from Engineering/Technology/Computing/Applied Science graduates are:

- Mastery of knowledge, techniques, skills and modern tools of their disciplines.
- Ability to apply knowledge of Mathematics, Science and Engineering.
- Ability to design, analyzes, conduct and interpret experiments.
- Ability to function in a multi-disciplinary team.
- Ability to identify, formulate and solve engineering problems.
- Ability to communicate effectively.
- Ability to understand professional, ethical and social responsibilities.
- Respect of diversity and knowledge of contemporary professional, society and global issues.
- Commitment to quality, timeliness and continuous, improvement with understanding of best practice and standards.
- Ability to integrate the engineering/IT-based solutions into user environment.
- Ability to engage in life-long learning.
- Ability to demonstrate independent critical thinking and problem-solving skills.

5.2 Accreditation Boards

In **USA**, ABET is the Accreditation Board of Engineering and Technology. This accredits programs at regional/national level under four categories: Applied Science, Computing Engineering and technology respectively through ASAC, CAC, EAC, TAC (Technology Accreditation Commission). ABET is a federation of 30 Professional societies representing fields of applied science, computing, engineering and technology. Accreditation is given to a program rather than to the institution and remains valid for six years. In USA, There are two types of accreditation: Accreditation is a non-governmental, peer-review process for post-secondary education: Institutional and Program-Specific. ABET is responsible for program-specific accreditation that assures that a college or University program meets the quality standards established by the profession. The first step is that an institution requests an evaluation of its programs that have produced at least one graduate batch. The institution conducts internal evaluation for those programs and completes self-study report based on the established criteria. ABET forms peer team with a chairman and one or two program evaluators. During the on-campus visit, the peer-team reviews course materials, study projects and sample assignment, and also interact with student, faculty and administration. At the end of the campus visit the evaluation team provides the report to the institute and allows correcting any misinterpretations and errors of fact. At the annual meeting of ABET commission members, the final report is presented and members vote on the recommended action. The information the institution receives identifies strength, weaknesses, concerns, deficiencies and recommendation for improvement. Accreditation is granted for six years.

In **United Kingdom**, degree qualifications are regulated by the government. Non-degree qualification are un-regulated. It is important to distinguish between the accreditation status of an institution, and the accreditation status of the qualification/programs it offers. National Database of Accredited Qualifications is maintained by the UK accreditation bodies subject to a regular external quality assurance reviews by the Quality Assurance Agency for Higher Education (QAA). UK Standard for professional Engineering competencies (UK-SPEC) by the Engineering Council UK adds two important competencies for Chartered Engineering — CEng or Incorporated Engineer- IEng:

- Ability to combine general and specialized engineering knowledge and to optimize application of existing and emerging technology.
- Ability to apply appropriate theoretical and practical methods to design, develop commission, operate and maintain engineering products, processes, services and system.

In **Singapore**, the Institution of Engineering, Singapore (IES) defines similar competencies as part of its accreditation criteria of engineering programs.

In **Australia,** there are two Accreditation bodies:

(1) Engineers Australia (EA) Provides accreditation for engineering programs normally carried out at every 5 years. Accreditation Board implements EA's accreditation policy).

(2) Australian Computer Society (ACS) provides accreditation for Information and Communication Technology. Expected competencies from the engineering/ICT graduates are similar to those mentioned above.

In **Japan**, the Japan Accreditation Board for Engineering Education (JABEE) adds the following linguistic competency.

- Japanese language communication skills including methodical writing, verbal presentation as well as basic skills for international communication.

In **India**, program-specific accreditation is done by NBA (National Board of Accreditation) (www.nba-aicte.ernet.in) under AICTE (All India Council for Technical Education), and institutional accreditation is carried out by NAAC (National Assessment and Accreditation Council) (www.naacindia.org) under UGC (University Grant Commission). Thus, accreditation in India is Government regulated. Grading and recommendation have weightage during consideration of permission to increase seats and grant in aid for R & D, modernization of labs. etc.

5.3 NBA Evaluation Criteria for Program(s)

Valuation criteria are broadly categorized into 8 parameters with varying weightage or UG and PG levels of Engineering programs. These include disciplines of engineering/technology/Computing. NBA is also responsible for accreditation of Pharmacy and Management.

NBA periodically conduct evaluation of technical institutions or programs on the basis of Guidelines, Norms and Standards specified and to make recommendations to AICTE council regarding recognition or de-recognition of the institution or program.

NBA criteria for Assessment of UG/PG as follows:

(1) Organizational and Governance	(UG: 80, PG: 50)
(2) Financial Resources, Allocation &Utilization	(UG: 70, PG: 50)
(3) Physical Resources (central facilities)	(UG: 50, PG: 50)
(4) Human Resources: Faculty & Staff	(UG: 200, PG: 200)
(a) Faculty	(UG: 160, PG: 160)
(b)Staff	(UG: 40, PG: 40)
(5) Human Resources: Students	(UG: 100, PG: 100)
(6) Teaching-Learning Processes	(UG: 350, PG: 250)
(7) Supplementary Processes	(UG: 50, PG: 50)
(8) Research & Development and Interaction Efforts	(UG: 100, PG: 200)
Gross Total	**(UG: 1000, PG:1000)**

The report by experts peer team submits the report and recommendation which are considered by another central committee to ensure uniformity in grading. A program is granted accreditation for three years if it scores between 650 and 750 out of 1000; whereas it will be awarded accreditation for five years if its score is 750 or above. Of course minimum score under each parameter/criterion must be above 50 percent. If it does not qualify minimum score of 65 percent then the institution apply again or accreditation after two years gestation period for substantial improvements to be carried so as to qualify later.

It is to note that out of the above 8 criteria, the criterion on Teaching-Learning Processes carries maximum weight of (UG: 350, PG: 250), next to that are R&D and HR criteria having weight of (UG: 100, PG: 200) and (UG: 300, PG:300) respectively. Thus 75% weightage is given to HR, T-L Processes and R&D. Crux of the issue is T-L process be innovation centric producing graduates with critical and systemic thinking and ability of generating ideas out of box that add value to the economy and society.

The criterion on Teaching-Learning processes is further detailed in terms of eight parameters as follows:

Teaching-Learning Processes	(UG:350, PG:250)
(1) Delivery of Syllabus Contents	(UG:100, PG: 60)
(2) Content beyond syllabus	(UG: 30, PG: 40)
(3) Academic calendar	(UG: 25, PG: 10)
(4) Continuous Evaluation process	(UG: 40, PG: 20)
(5) Utilization of Labs & equipments	(UG: 40, PG: 30)
(6) Information access facilities	(UG: 55, PG: 40)
(7) Student-centric learning	(UG: 35, PG: 40)
(8) Students' Feedback	(UG: 25, PG: 10)

5.4 NAAC Assessment Criteria

NAAC so far accredits at institution level, however plans to accredit even program(s). The accreditation criteria are quite exhaustive and largely quantifiable. Efforts are being made to maximize quantifiable indicators and minimize subjectivity in assessment.

NAAC accredits Institutions/University/Affiliated Colleges/Autonomous Colleges.

Assessment criteria for University (u), Autonomous Colleges (a), and Affiliated or Constituent Colleges (c):

- Curricular Aspect (u = 15%, a = 10%, c = 5%)
- Teaching-Learning Processes (u = 25%, a = 35%, c = 45%)
- Research, Consultancy & outreach (u = 20%, a = 15%, c = 10%)
- Infrastructure & Learning Resources (u = 10%, a = 10%, c = 10%)
- Student Support & Progression (u = 10%, a = 10%, c = 10%)
- Governance & Leadership (u = 15%, a = 15%, c = 15%)
- Innovation Practices (u = 5%, a = 5%, c = 5%)

Major focus is on Teaching-Learning Processes. NAAC assessment weight is 25% for university, 35% for autonomous colleges and 45% for affiliated colleges.

NBA assessment weightage for Teaching-Learning Processes is 25% for PG and 35% UG Programs

NAAC criterion on Teaching Learning Processes covers issues, such as:

- Transparent admission process
- Learner-centric teaching & learning
- ICT enabled teaching processes
- Continuous monitoring of students progress
- Adequate qualified faculty
- Open and reliable evaluation processes

Essential aspect is methodology of teaching-learning that promotes innovation and critical thinking.

Industry demands technological, analytical and communicative skills, Sound knowledge of basic science concepts, ability to apply professional knowledge, entrepreneurship and presentation skills.

5.5 Comments on NAAC Grading

The present grading system is linear with Cumulative Grade Point Average (CGPA) over a scale of 0–4. Grade “A” is awarded on scoring in the range of 3.01–4.00, grade “B” for the range of 2.01–3.0, “C” for score in the range of 1.51–2.00, and “D” for the score 1.50 or below. This linear grading system needs to be reviewed in the light of the following observations.

(1) Law of diminishing returns — to improve next one unit, much more additional efforts are required over those done for previous one unit. Higher grade would demand proportionately larger efforts. It would be asymptotic non-linear function ($1–e^{-x}$).

(2) Many indicators correspond to absolute numbers. Universities with large number of students and faculty will score higher. These may rather be relative in terms of percentage of the recommended number of faculty based on number of students.

(3) There is need to assess the students’ teaching aptitude developed during the program as well as the students’ ability to effectively interact with neighborhood and provide technology based easy to use affordable solutions in local language. A mini project with these objectives would be desirable.

(4) Pass percentage is considered for ranking the institutions. But the excellence ranking should rather be the percentage of students who crossed the threshold of 75 percent.

5.6 NAAC Benchmark Document under Revision

The draft model for developing quality benchmarks being proposed by NAAC contains the following salient points.

(1) About 40 indicators are proposed touching all 7 criteria and 36 key aspects used by NAAC for assessment. These may be reduced to 30+. Indicators include aspects relating to inclusive concept of quality like access and equity.

(2) The indicators are designed in such a way that replies can be measured on a scale and percentile can be obtained.

(3) Universities scoring 95% and above would be considered suitable to highest CGPA range of 3.67 to 4.00; score of 90% would correspond to CGPA of 3.34 to 3. 66 and score of 85% and above would correspond to 3.01 to 3.33 CGPA.

(4) Indicators range from “student drop out %” to “number of Post docs and international awards”.

6. Case Studies

6.1 Innovation and Creativity: The Core of Computing Curricula

We cite a specific case of Computer Science curricula that went on under revisions to ensure that graduates are empowered with abilities as specified by a number of professional societies to meet the requirement of integrating science, technology and global concerns. IEEE Computer, Feb 2010 (pp. 98–100) discusses need to infuse the principles of entrepreneurship and innovation in computing curricula to equip students with the tools and skills necessary to succeed.

Kauffman Foundation (http://kaufman.org) argues that entrepreneurship should be an essential component of UG programs. Entrepreneurship encompasses numerous fields of study and wide range of human activities, including Culture, economics, law and technology.

In order to promote Innovation and Creativity knowledge areas that could be incorporated as modules are Concept Analysis, Market Research and Analysis, Feasibility & Business Plan Development, Intellectual Property, Financial Planning, Global Entrepreneurship, Integrating Open Technology, Open Standards.

Inclusion of entrepreneurship in the curriculum will also meet specific ABET criteria for accrediting Computing Programs. Moreover, this would also expose students to importance of continuing professional development

National Knowledge Commission of India has strongly recommended innovation-centric education and various steps to take. It is obligation to prepare our students to contribute to a global workforce and the growth of economy of the country.

6.2 Paving a Way to Innovation

We notice technological shift from Proprietary Technology to Open Technology; from Centralized Computing to Distributed Computing; from Single Supercomputer to Cluster of Computers; from Mainframe to PC/Client-Server Configuration; from Product to Service.

IT Innovation Framework would determine Investment worth, open architecture, compatibility, simplicity, ease to use, relief to user's pain. Diffusion of innovation is considered in the context of Customer, Competitor, Technology Complexity, Eco-friendliness.

US spending have increased on R&D on Green Technology that is more energy-efficient technology such as Low-power devices, etc. Cloud Computing is emerging in response to the priority on developing Green Technology.

SaaS: Software as a Service, on subscription based model, saves investments in IT infrastructure and provides faster time-to-value to customer with simple set-up. Issues of concern include Security, Customization, Availability and Scalability.

SOA (Service Oriented Architecture) based open standard allows integration and interoperability of different applications. Heterogeneous IT systems need to be re-designed to fit to SOA.

From Business Analysis Perspective, SaaS is not high scorer and not ecosystem friendly, SaaS has limited compatibility with on-premise IT-Solutions. SaaS interacts with users; System Integrator based on SOA would ensure optimal sharing of resources. SOA and SDP (Service Delivery Platform) would augment open innovation.

Web 2.0 facilitates open innovation through social networking and sharing global expertise. Web 2.0 offers capabilities for connecting and empowering individuals, communities and enterprises and providing access to resources — Knowledge, Technology and Market. This enables companies to share costs of research while capitalizing on creativity they harness. Business Mantra is "grow or die"; Whereas Technology Mantra is "innovate or perish".

7. India's Aspiration for Inclusive Innovation

In India, not more than 3% of the applicants are able to get enrolled at the technical institutes of national repute. About 230 thousand Bachelors' (engineering) degrees, and around 20,000 Masters' degrees and around 1000 PhDs. were awarded in India in 2006.

It may not be pleasing to note that 511+ Ph.D.s were awarded in 1982–1983 and in twenty years the number has not even got doubled in twenty years (911 in 2003–2004). The percent of doctorates viz-a-viz Bachelors' degrees in engineering is 1 in the case of India and in the case of USA it is 10 and in UK it is 8. This percentage needs to be boosted to achieve global targets.

In India there are around 1500 institutions granting engineering education at the graduate level. 10% of those can be considered worthy of granting PhDs. Around 390 institutions offer Master's degrees in engineering (3% of M.Techs are produced by research universities). Over 75% of the engineering graduates are taught by privately aided engineering colleges. There are around 400 Universities. China is a home of 1200 Universities. During 1991–2001, number of PhDs in India increased only 20%, whereas in the same period, China had an 80% increase in its PhDs researcher.

India's GER (Gross Enrollment Ratio) is 12.9% compared to the immediate global competitor China having 23%. World average is 26%. USA's GER is 34%.

There is 80% shortage of Engineers. The ratio of PhDs compared with engineering graduates is very low. If 70,000 students enroll as engineering graduates, only 1,500 go for higher studies. But irony is, out of those 1,500, only 250 enroll for PhDs.

This leads to the inference that aptitude for innovation and research is not encouraged building up during graduate studies.

8. Steps to Augment Innovation

Following steps are suggested to augment innovation in education in India.

(1) *Curricular reforms*. Engineering curricula of 4-year BTech/BE programs need to be revisited to make it broad-based, flexible and practice-predominant. 5-year integrated program may be launched as BTech in “Specific Engineering and Innovation management”. HSS, Maths and Basic Science courses may be added in this new program.

(2) *Faculty development*. Over 75% engineering graduates pass out from private colleges which often employ fresh graduates for teaching. Faculty development programs with proper evaluation need to be conducted periodically. Like B. Ed and M. Ed, 6-months modular program on Engineering Education may be conducted for the engineering faculty. This may be made mandatory to be eligible for teaching in an engineering college. Moreover faculty should be on regular contract appointment for minimum 3 years.

(3) *Academic Leadership*. Often directors/principals are for short duration and cannot function with autonomy and as per rules to ensure high quality standards. They should be appointed on regular contract for minimum 3 years. Management should not be able to sack them without proper enquiry.

(4) *Renewal on higher quality standard*. AICTE may consider making it mandatory to raise the quality level by securing above 75% on renewal of accreditation. Else the institution may be advised to request again for accreditation after a year. This will promote innovation, R&D and effective interaction with industry.

(5) *Innovation-conducive pedagogy.* Delivery of curricular content should incorporate comprehension-conducive methods — introducing puzzles, case-studies, open-book quizzes, time bound team exercises, group discussion, etc. Beyond syllabus coverage of related concepts and case studies, and innovation in project work will promote systems thinking and exploratory learning. E-tutorials/lectures by eminent professors are freely downloadable from sites of MIT, NPTEL, etc. These may be selectively integrated into class-room instruction. There is need to pay more attention to practicals and team projects. A mini project report in local language describing interaction with people, problem-solving approach, innovation ideas and implementable solution should be mandatory. NBA and NAAC may consider giving due weightage for this activity.

(6) *E-Skills development.* In addition to knowledge of technology, quality and standards, system integration skill also needs to be developed. Skills may relate to development of thought process — Recall for linear thought, Relate for relational thought, Inference for perceptional thought, and Interface for holistic thought to theorize.

(7) *Adopting a village.* Under NSS (National Social Service) scheme, institution may adopt a village, mohalla or slum dwelling and transform it to better state with quantifiable measures such as literacy, income growth, entrepreneurs, employment, and health condition. Time-series of progress may be considered by NBA/NAAC.

(8) *Professional communication.* Communicative skills are often confined to teaching English language rather than creative writing, professional technical writing & presentation. Communication skills need to be developed even in local language, as most of the graduates will have to interact with local people and create newer business avenues within the country.

9. Summary

Innovation is path of progress and happiness. Innovation is sown and sprouts in educational institutions; grows and blossoms in work place — industry, government or academia. Innovative aptitude may be developed and groomed up. Innovation may be viewed as multi-dimensional activity involving offerings (What), beneficiaries (Who), processes (How) and points of presence (Where). Innovation may be categorized as open or closed. Open innovation incorporates business model to create value and promotes purposive inflows and outflows of ideas, knowledge and technology. Innovation in education is of open type utilizing internal (syllabus-based, in-class) and external (beyond syllabus, visits & interactions) knowledge and skills. Team projects and societal interaction to provide affordable solution will instill innovation in affective domain. Accreditation boards are yet to come out with adequate *quantifiable* indicators for innovation-centric teaching-learning processes. Overall grading system should keep in consideration the law of diminishing returns and should change from linear scale to non-linear scale. It is proposed to provide direct Vertical Mobility to ITI pass-outs of Vocational Training through a bridge course to get into Engineering program. The educational institutions may take up *study of skill sets in Jugaad* or unstructured/intuitive innovations and develop framework to re-construct technologically. The developing nations will greatly benefit of unstructured innovations and creative ideas of people. Future lies at the bottom of pyramid. Innovative societies at large will make the fortune. Innovation-centric T-L processes need to be promoted in schools, colleges, institutions and universities.

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