NATIONAL KNOWLEDGE COMMISSION

REPORT OF WORKING GROUP ON ENGINEERING EDUCATION

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Prof. M.S. Ananth
Chairman
Working Group

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Executive Summary

Engineering education consists of three well-defined aspects knowledge, know-how, and character. The knowledge component enables one to understand what one learns in relation to what one already knows and provides the continuity in education while know-how is the ability to translate knowledge into action. The knowledge component has an invariant core that consists of fundamentals based on universal laws and an outer layer of constantly improving and rapidly expanding empirical knowledge of particular systems, constantly changing applications of increasing sophistication and complexity and constantly improving tools. Education thus described is a combined responsibility of academia, industries, professional associations and society. While universities should focus on teaching the invariant core and the nature of empirical knowledge and tools, industry should focus on educating their employees on specific aspects of empirical knowledge, tools and application. Character is perhaps the most important component but character building processes are difficult to define and implement.

Engineering institutions in India currently account for intake of more than 5,00,000 students in Bachelor's program, around 30,000 in Master's program and less than 1000 in PhD program. The number of institutions has also grown by an order of magnitude in the last two decades, mostly in the private sector. This rapid expansion has raised serious concerns about the quality of engineering education in these institutions. Over the next decade, India will have two significant opportunities in the form of manufacturing and engineering services outsourcing in addition to growing opportunities in business process outsourcing and information technology outsourcing. In order to meet the growing demand, the capacity of engineering education especially in post-graduate (PG) programmes needs to be tripled while simultaneously enhancing quality. Currently, most graduates do not possess the skills needed to compete in the global economy, and industries have been facing a consistent skills deficit. The challenge for universities is to work out a healthy balance between wholeness of knowledge and specialization that caters to current technological demand. Institutions of higher learning traditionally been financed by government are slow in responding to changes in the environment. The challenge is to create organizations, private or in the public private partnership (PPP) mode with well articulated vision and goals which can respond meaningfully to such challenges. Research in universities is sub-critical for number of reasons that have to be addressed.

The most serious challenge is the dearth of well-qualified faculty and issue of attracting and retaining motivated faculty. PhD degrees are pre-requisites for teachers in institutions that supply man-power for research and for development of cutting-edge technologies. The number of faculty required is far above the current number of PhD graduates. The pre-requisite of holding a PhD degree for becoming a faculty member should be relaxed to Master's degree in institutions that offer only undergraduate degrees. It is also recognized that it is important for teachers in such institutions to have a breadth of knowledge and some understanding of what the industry needs. Hence, it is desirable that Masters Program follow two approaches – one which requires a thesis submission at the end of the program and another that does not, but with more course-work

instead. Currently, due to a dearth of those with any PG degree, engineering institutions employ fresh B.Tech/B.E as faculty. This is not desirable in the long run and it is necessary to ensure that opportunities are available to the faculty to continuously upgrade their teaching skills and knowledge.

The next serious issue is the lack of autonomy in the majority of institutions (under affiliating universities). The system of affiliation restricts the freedom of teachers to experiment with different methods in the classroom. Teaching-learning processes cannot bear desirable fruits in the absence of complete autonomy to teachers and institutions, while at the same time ensuring their accountability. From their part, teachers should ensure that significant amount of course time is devoted to discovery-based (which includes project-based) learning in addition to traditional lecture modes of transmitting knowledge. Teacher feedback and evaluation is a significant part of the teaching learning process which needs to encouraged and conducted in a more scientific manner. Teacher student relationship outside the classrooms should be encouraged by providing different avenues in which the two can interact informally.

A credit based semester system which offers flexibility to follow different learning pathways to students should be introduced in all institutions. Undergraduate (UG) education is a major indicator of the health of the higher education. In this regard, the Committee has therefore suggested a framework for adoption by the educational institutions. For PG education, institutions are encouraged to develop their own framework. Industries need to work closely with academia to provide the latter with a 'reality check' on what is taught and for providing opportunities like summer training to students. A major revamp of laboratory course work is needed.

It is difficult to think about engineering education without science education. Keeping this in mind, the Committee also recommends that 4 year Bachelor of Science (B.S) program be introduced on the lines of the 4 year B.E/B.Tech program. A pragmatic approach will be to start with institutions where the engineering programs are strongly science based. A common core of engineering/science in the first two years and a flexible professional stream in the last two years is desirable. Following this 4 year program, students must be allowed to pursue a PhD program directly in their chosen areas of interest with considerable flexibility in terms of their specific background in sciences or engineering.

A constant dialogue among Educational Institutes, Industries and Government through seminars and workshops is necessary to keep each other informed about the latest trends and issues. Many consortia like National Association of Software and Service Companies (NASSCOM), Confederation of Indian Industries (CII) etc have created a major workforce development platform and launched several initiatives, in partnership with the Government and academia that aim to bring positive changes to the Indian education system. Finishing schools run jointly by educational institutions and industry can train graduates especially in soft skills to make them more suitable for employment. Polytechnics should be opened and operated in public private partnership mode. Industries can also explore the possibility of starting educational training programmes for their employees with experts from the academia as consultants.

The Committee recognizes that brick and mortar model of engineering education cannot meet the exponentially increasing demand for higher education. It endorses the recommendations made by NKC on Open and Distance Education. World class infrastructure should be developed and enabled for improving the quality access and in the meantime, different modes of learning should be explored both offline and online. Feedback mechanisms to ensure continuous improvement in pedagogy should be put in place. Distance Education should be used to drive Faculty Development Programs in a major fashion. The Committee also recognizes the long term value of initiatives like that of Ministry of Human Resource and Development (MHRD) towards development of a One Stop Education Portal.

Engineering Education is administered by the MHRD through the All India Council for Technical Education (AICTE). AICTE provides the guidelines for starting new programmes in technical education and is also charged with accrediting the programmes through the National Board of Accreditation (NBA). While AICTE is in principle autonomous, it has been politically influenced in practice leading to considerable loss of credibility. There is a need to establish an apex independent regulatory authority that can achieve the objectives of regulation without political interference. All institutions must be mandated to obtain a certificate of audit annually which can be called 'Chartered Educationist Certificate'. Chartered Educationist should perform the role of auditing. In order to ensure success in regulatory processes, multiple independent agencies should be established. At the same time, it must be made compulsory for all institutions to disclose on their website all the information necessary for students, parents and other stakeholders to make informed decisions.

CHAPTER 1 - OVERVIEW

1.1. INTRODUCTION

Engineering education consists of three well-defined aspects knowledge, know-how and character.

Knowledge enables one to understand what one learns in relation to what one already knows. It can be organized into intellectually tight compartments that can be conveniently taught as courses in a conventional curriculum. Each knowledge-area has four components:

- an invariant core
- exploding volume of empirical knowledge
- constantly changing applications
- rapidly changing tools

The invariant core consists of fundamentals based on universal laws that provide a phenomenological description while the outer layer consists of constantly improving and rapidly expanding empirical knowledge of particular systems and of constantly changing applications of increasing sophistication and complexity [1]. The invariant core provides the continuity in education while the applications provide the excitement and the education relevant to the current demands of the industry. Although the fundamental theory is itself invariant it should be emphasized that applications often provide new insights into the working of the theory. The rapidly changing tools (the most obvious one being the ubiquitous computer and associated software) have a very significant effect on education not only in terms of problems that can be tackled but to our entire approach to a subject.

Universities should not be overly concerned about 'coping with' the rapidly exploding empirical knowledge of particular systems. Individual industries are better equipped to cope with this explosion and can and should 'train' their employees to deal with this aspect of education. It has become customary for industry to try to 'save' this cost by outsourcing this job to universities. The importance of acquiring the 'latest' tools and incorporating training in the use of such tools is of practical importance. At the same time it should be recognized that such training is not as important a component of university education from a conceptual or pedagogic point of view as the software vendors or the user industries seem to believe.

Know-how is the ability to put knowledge to work. It requires the purposeful organization of knowledge from many different areas of learning. Know-how is taught through design courses, project work, industrial training and other opportunities for individual initiative and creativity. Elective courses on technology often provide descriptions of successfully implemented know-how while those on emerging technologies describe attempts at doing so.

Character traits are easy to recognize but character building processes are difficult to define and implement. Character traits such as honesty, truthfulness, integrity, initiative, competitiveness, self-esteem, leadership and the ability to work both alone and as part of a team have an invariant value. But it is not all clear how these get imbibed in educational systems that cater to very large and diverse clientele. In the pre-scientific and pre-technological era preceding the wars, religion did play a significant role in character building. This is no longer true and the trend is that with technological advancement the secular intelligentsia plays an increasing role in social and ethical development. The educational institutions now, more than ever before, have been assigned the responsibility of character building using secular tools. The Humanities can play a central role. So can Co-curricular activities.

It is clear that education as described above is too much of a responsibility to be left to universities alone! Of the knowledge components the teaching of empirical knowledge specific to individual industries and use of tools such as industry-specific software are logically part of the 'training' that industries themselves should provide while the university can provide the framework for assimilation of such knowledge. Again significant part know-how should clearly be learnt on the job. Character development is the joint responsibility of all parts of society – the family, the educational system and the work environment.

1.2. CORE VALUES

Education neither begins nor stops at the University. Higher education is concerned with the refinement of the mind, with living gracefully with partial knowledge. It is concerned with survival skills of two kinds as described in the next section. Finally it is about teaching a student how to open a tap not about filling a bucket! The primary purpose is not to 'train' the student to be 'fit for employment' in any specific industry. The university emphasizes unity in knowledge while the industry thrives on differences. So while being sensitive to the needs of the industry the university concentrates on wholeness of knowledge and even while pursuing narrow specializations in research, driving force continues to be intellectual curiosity than market goals.

In this context it is worth reiterating the core values that an educational institution should be committed to maintain and nurture.

- Autonomy and academic freedom are pre-requisites for the creation and sustenance of an atmosphere of free enquiry that is the essential character of the university.
- Teaching is a unifying activity, a commitment to create a community of learning in which students join in discovering knowledge and in putting it to use.
- Research, both routine and creative, and its dissemination through publications and conferences are central to the intellectual character of an institution of higher learning.
- Information dissemination through popular articles on science and technology is an important responsibility. A well-informed public is the

only reliable protection in the long run against misuse of technology in development.

The impact of the education process on economic development appear to be so obvious to all that it has become cliché to call upon the university to participate actively in the process. The long term benefits of educational process that encourages development of a questioning and thinking mind are often ignored in this utilitarian view of the educational process and it is important that we find champions for this cause among the stakeholders of the university system. The next section attempts to articulate these ideas further.

1.3. SURVIVAL SKILLS

Education today is concerned with two kinds of survival skills – those for the individual and those for civilization as a whole. The skills for the survival of the individual or institution are *information, resourcefulness, an elastic conscience and some professional as well as 'soft' skills.* Information is picked up from many places - television, radio, newspapers, magazines and even conversations with others and has increased explosively in recent years. Shrewdness is picked up "on the street". The urban environment today throws together people with widely different world-views and occupational compulsions: the social worker and the marketing manager, the environmentalist and the industrialist, the conservative and the liberal and so on. It is increasingly necessary for each to be able to appreciate the other's point of view and to develop an elasticity of conscience for peaceful coexistence and meaningful debate. Except for professional skills, formal engineering education is considered to have little to do with the imparting of these skills. 'Soft' skills are best learnt by 'diffusion' on the job. Teaching them at the university can often lead to an excessive emphasis on 'form' over 'substance'. While the reality of the job-environment may require these skills, emphasising them at the universities runs the risk of breeding cynicism in their students.

On the other hand, the skills for the survival of civilisation as a whole are *knowledge, an abiding faith in the power of professional knowledge to improve the quality of life of all people and a sense of ethics, objectivity, aesthetics and history.* Educational institutions have an important role to play in this regard.

Commercial job-oriented courses provide knowledge and know-how in the form of currently required skills for the survival of the individual. The fees they levy are determined by the perceived market value of the skills they trade in. They satisfy a current social need and are therefore a necessary supplement to the main-stream institutions. In the larger interests of nation the education imparted in the latter should include a significant fraction of skills for the survival of society.

In the long-range interests of the nation, it would seem advisable for government to wholeheartedly support activities that impart skills for the survival of civilisation without enforcing bureaucratic controls while individual institutions should be asked to find the resources to support all other activities.

1.4. THE CHALLENGES

The rapidly changing environment of today calls for greater flexibility and responsiveness in the university's operations in its march towards functional and financial autonomy [2]. Coping with these changes while preserving its core values poses a variety of challenges that may be articulated conveniently under various heads as follows:

- Meeting Increasing demand: Universities are under pressure to provide education for at least three times the present student population within the next decade while maintaining their excellence and high standards of performance. The most serious challenge in this regard is the dearth of qualified faculty. They must take full advantage of developments in ICT since the brick-and-mortar model is likely to be unaffordably expensive.
- Knowledge-explosion: Universities have to work out a healthy balance between wholeness of knowledge and specialization that caters to a current technological demand. While the university is the sole champion of the former the industry is more concerned with the latter.
- Generic industry skills for engineers: In the fast evolving industry requirement regarding generic skills, so necessary for gainful employment, academic institutions must consider an inclusive approach to integrate those skills in the teaching learning process for the holistic development of the individual. Some of these skills include i. Problem Solving and Logical Reasoning (Analytical Ability), ii. Process Orientation (Attention to Detail) iii. Learning Ability iv. English Communication (Written and Verbal i.e. non-voice) and v. Programming fundamentals(the generic domain)
- Governance: Institutions of higher learning have traditionally been government financed, ministry directed centres of higher education resulting in development of bureaucratic controls that stultify innovation and creativity. The challenge is to create organisations with well articulated vision and goals that generate revenue by charging the users rationally for their services, through seeking donations, creating endowments and entering into collaborative alliances with institutions in India and abroad in the pursuit of these goals. The challenge is to move from being another arm of the government to those that cope with contemporary social realities and influence Government policy while remaining apolitical, autonomous, socially relevant and yet sufficiently detached to serve the purposes of objective evaluation and constructive criticism. The challenge is to be able to actively protect themselves from all outside efforts to wear away their autonomy and academic freedom while playing an active and full-filling role in societal development.
- Resource generation: Apart from Government support, the primary resources for higher education all over the world are the fee collected from the UG students and revenue generated through industrial consultancy and sponsored research. There are good non-commercial reasons that limit the fees that can be collected from students. The Government (directly or indirectly) is the largest funding source for

sponsored research. Increase in resource generation from industry is a slow process especially in the case of educational institutions that are governed by Government-regulated procedures.

- Retaining a perspective: Rapidity of change creates historical attitudes. Universities should educate students to cope with the confusion of values that follow from technology's threats to 'sweep humanity off its cultural feet'. They have to identify and preserve that which is good in their past while dealing with contemporaneity and relevance. They should create a vibrant community of learning that is willing to articulate, profess and defend its core values while being open to healthy winds of change.

1.5. TEACHING, LEARNING AND CREATIVITY

It is not out of place to point out that notions about teaching that are consistent with the modernistic view of education have perhaps been best articulated in the form of a few principles by Sri Aurobindo [3]. The first principle is that nothing can be taught; the teacher is a helper and a guide; his business is to suggest not impose; he does not impart knowledge but shows the student how to acquire it for himself. It is worth our while to recall the advice that Prof. Kelkar the first Director of IIT Kanpur is reported to have given a young faculty member who was upset about being unable to cover the portions ' Young man, I did not hire you to cover any portions but to uncover a part of them'! The second principle is that education cannot be forced on an unwilling mind. Indeed the mind has to be consulted in its own growth. The third principle is to work from the near to the far. Illustrative examples in teaching should be drawn from the student's own environment. We have not been successful in implementing the second and the third principles although they are clearly important. A fourth principle is that suppleness and comprehensiveness of the mind are increased not by the number and variety of subjects for study but by diverse approaches to the same subject. Sri Aurobindo also identified the important attributes that a student should acquire as the capacity of attention, concentration and faithfulness of memory.

Our understanding of the learning process that is in conformity with the above has been elucidated by the work of Roger Sperry and his co-workers [4]. They showed that the two sides of the brain think in fundamentally different ways: the left is logical, thinks in words and uses step-by-step sequences while the right brain uses visual images and intuition to draw conclusions. The creative process itself has four discernible stages:

- The preparation stage of information gathering by the left brain
- The incubation stage, during which the right brain tries to see the "whole picture"
- The illumination stage in which the right brain's insight and intuition generate possible solutions
- The verification stage in which the left brain logically tests the solutions and organises and elaborates the correct solution into a finished form.

University education tends to be dominated by logic. However it is the synergistic relationship between the left and right halves of the brain is the real basis of creativity and learning. The freedom from logic and structure is what makes the visual thought process of the right brain so effective in generating ideas. Since most of the ideas so generated fail, when tested logically, the left-brain is equally important in the creative process.

Historically the Indian (and the Greek) educational processes have been predominantly intuitive with an emphasis on authority. Logic was secondary and the last step in the creative process was often neglected.

Disciplined rote learning that comes easily to a young mind was therefore recommended as a desirable attribute. Traditionally it was decreed that the wisdom to realise the importance of knowledge came to man long after the sharpness of the young mind in learning was blunted. The responsibility of the teachers was to focus the young mind on knowledge that their mature minds perceived as useful. This "data-gathering" step taken together with the last three steps described above is clearly an important part of the creative process!

1.6. SOME CONCERNS

The academic environment differs from the industrial environment in a fundamental way: it is the most forgiving of environments – one in which mistakes are the true stepping-stones to learning. Experimenting with new paradigms and retaining a willingness to do so are therefore important characteristics of a university. Research is the relentless pursuit of truth and demands faith in the scientific process, an uncompromising integrity and an ambience that nurtures creativity and academic freedom. President Charles Vest warned Massachusetts Institute of Technology (MIT) not to allow its "pre-occupation with all-consuming routine to lead to a suspension of faith" [5]. He added that "the greatest problem for a university is not its somewhat disordered structure but the administration's tendency towards bureaucracy..…*that can upset the balance between trust and accountability, import certain values into the community under the guise of incentives. Such incentives are, indeed, the last gasp of an academic institution in trouble".* Based on a principle explicitly articulated by Lord Macaulay in 1830s the rules governing Her Majesty's subjects in England were based on trust while that of the natives in Her colonies were based on mistrust. Since independence we haven't changed this basis but merely replaced the white sahibs by brown ones.

Institutions of higher learning should guard against the dangers of an undue emphasis on resource generation in an academic environment [6]:

- The system is likely to become money-driven rather than scholarship driven.
- Graduate students are likely to be trained as technicians in narrow areas in order to meet the unenlightened demands of funding agencies.
- The most "successful" faculty are likely to be those who can write proposals and generate research funds rather than those who are knowledge-driven and can enthuse students into learning and creative research activity.

- Teaching is likely to be neglected.
- The administrative component is likely to grow at the expense of its academic counterpart and governance by "gentleman's agreements" is likely to be replaced by rules, regulations, grievance- redressal committees and legal machinations.

2. THE INDIAN CONTEXT

2.1. ENGINEERING EDUCATION

Engineering Education in India has a pyramidal structure. At the peak of the pyramid are a few elite institutions. These elite institutions are very important for India and the world. They may become three-fold in the coming years through new entrants and increase the reach by expansion of capacity in existing institutions. Other countries - USA, Japan, Germany etc. - have their spread too and very few peaks. Elitism is not built by money alone. Teachers, students, culture and above all time are required. In such elite institutions the emphasis can be on global level excellence in teaching, research, and consultancy. Competition and collaboration between these institutions will lead to many creative and innovative educational methodologies in India and set trends for the other engineering colleges to follow.

The industrial and service sectors need a large number of professionals. Industries survive primarily on the graduates of the colleges from the second and third level institutions of India. One problem is the lack of soft skills in these graduates as far as Industries are concerned. There are a number of private institutions thriving as "finishing schools" that help in teaching these skills. There is an acceleration of growth of engineering colleges and finishing schools only because there is a demand for the graduates despite complaints about the quality. An important social factor to note is that these colleges have come up in the backward districts of India (because of low land costs for large campuses) and help many rural girls and boys enter higher education. There is therefore a strong case enhancing the reach and quality of engineering education through such colleges.

Table 1 gives a summary of the different types of engineering institutions and their key characteristics. The purpose of this table is to qualitatively summarise the quality of institutions. There are basically four kinds of engineering institutions: Private-unaided, Private- aided by Govt, State Govt aided and the ones under Universities. There are exceptions to each of these but the qualities noticed against each of these are applicable in a broad sense.

Table 1: Brief Description of Existing Engineering Institutions

Key Characteristic	Private – Unaided	Private – Grants-in-Aid	State Govt. Aided (DTE)	University Constituents
Vision/Mission	Absent	Partial	Mostly Absent	Mostly Absent
Finance	Adequate	Inadequate	Struggle	Struggle
System Inertia	Less	Better	Considerable	Massive
Administrative Autonomy	Management Dominated	Slightly Better	Negligible	Negligible
Academic Autonomy	University affiliation & size would be the deciding factor. With Deemed University Status, situation would be conceptually better.			
Physical Infrastructure	Glossy Grows Faster	OK, Growth Possible	Old & Outdated, No major Initiative taken to Upgrade it	
Maintenance	Good	Good	Much Desired	Much Desired
Faculty Resources	Market Driven, Hire & Fire Inexperienced Temporary Hand		Myriad of Restrictions, Vacuum at the Top, General Shortage	
Support Services	Relatively Poor	Relatively Poor	Old and Outdated	Old and Outdated
Geographic Access	Poor – Rural Setting	Poor – Rural Setting	Mostly Urban	Mostly Urban
Learning Resources	Decent in IT, ITES	Decent in IT, ITES	Old and Outdated	Old and Outdated
Laboratories	OK in IT & ITES, Else very Poor		Old Laboratories not upto Mark	
Internet Bandwidth & Nodes	Marginal/ OK	Marginal/ OK	OK /Marginal	OK/Marginal
Industry Interaction	Poor Proximity	Poor Proximity	Good Possibility	Good Possibility
Stakeholder Preference	Poor	Slightly Better	Good	Very Good
Student Admissions	State Level Admission Test + Management Quota			
Student Performance Indicators	GATE, CAT, TOEFL, GRE, NAC-Tech* *(NASSCOM Assessment of Competence –Technology)			
Change Agent	Market	Market	Grants if no focus on R&D	Grants if no focus on R&D
R & D	Nil	Some	Little	Better

2.2. POLYTECHNIC EDUCATION

The rate of growth and the quality of polytechnics have decreased in recent years. This report does not discuss the issues related to them. It goes without saying that they play an important role in trying to meet the manpower requirements of the industry at the floor shop level. Tier 2 and Tier 3 Colleges and national labs and industries can help them. Instead of "theory" classes, polytechnics should focus on actual skills by working in the "field". Industries should play a major role in the development of these institutions.

While education in the Polytechnics is primarily concerned with survival tools for the individual it is important to recognise that they cater to floor level needs of the industry and are sought after by the poorer sections of the society. It seems therefore desirable for the Government to adopt the public private partnership (PPP) model in ensuring the quality and reach of education and training in these institutions. They should be ideally managed and run by the industry in the PPP mode. The industries (by themselves or through their sub-contractors or vendors) should give practical training to the polytechnic graduates.

3. MANPOWER DEMAND

Before independence, the demand for engineers in India was mostly for designing and constructing large irrigation projects. However, majority of civil, electrical and mechanical engineers were employed for maintenance related work. Post independence the demand for design/development engineers was created by the Atomic Energy Commission, Council of Scientific and Industrial Research (CSIR) laboratories, defence organizations, Department of Science and their offshoots and also for large irrigation projects [7].

In the last decade, the Information Technology Outsourcing (ITO) and Business Process Outsourcing (BPO) industries have seen substantial off shoring. A survey done by McKinsey Global Institute [8] shows multinationals find only 25 percent of Indian engineers employable: A NASSCOM report [8] foresees a shortage of 500,000 knowledge workers by 2010, 70% of which would be in the BPO industry. Currently, ITO and BPO industries respectively find only about 25% of technical graduates and 10-15% of general college graduates suitable for employment [8].

India also needs to pay attention to the third major growth stream – Engineering Services Outsourcing (ESO). While off-shoring IT-enabled and BP places significant weight on the labour cost arbitrage, ESO is about expanding global innovation capacity in design, research, innovation and engineering. Hence unlike BPO, where the primary requirement is the communication skills both for the export and the domestic markets and foreign language skills, mostly for the export market, along with the quality education and cultural fit, engineering services require that candidates also possess a good grasp of engineering fundamentals in addition to the familiarity with sector-specific software and hardware. The number of R&D sites in China and India have been growing at a fast pace. In order to attract the off shoring industries in core engineering services, India would need as many as 2,50,000 skilled engineers working in engineering services by 2020. This workforce currently approximates only 35,000 [9].

Another domain that requires special attention is rural development in the country. The development of 70% population living in rural India depends upon innovative technology-based solutions which could mitigate the challenges associated with development. Equitable growth within the country is not possible as long as this sector remains in a neglected state. Along with the requisite of knowledge and skills to work in this area, the incentives to motivate scientists and engineers are an issue that needs to be addressed.

As competition from around the world intensifies, India needs to urgently improve the quality of education.

The rapid growth of engineering institutions especially in South India and the inadequate number of PhDs have together created a shortage of faculty across disciplines and institutions.

The number of institutes has doubled thrice since 1980. Though this is impressive, but the region-wise distribution of institutions and sanctioned intake of students show serious regional disparity [see Annexure 1]. While there are around 268 institutions in the southern region, there are only 9 institutions in eastern region [10]. The main responsibility for equity and access lies with the Govt. Reservations in higher education alone may not be the answer. Affirmative actions by Industry have limitations in terms of quantity. Govt. should consider setting aside funds for helping poor students get through the entrance tests and later pay the fees in institutions of the students' choice. Government funds should go to the poor and needy in the form of grants and soft loans for coaching and for fees after admission rather than negotiate with the institutions for lower fees.

PG education in Engineering and Technology had a late start in our country. At the time of India's independence only 6 institutions offered PG programmes in Engineering and Technology to about 70 students in all. The number of these institutes reached 321 in 2003. 1552 PG programmes were recognised in hard-core engineering with the total sanctioned intake of over 26,000 candidates [7]. The number of PhD's in the Engineering is around 800 and 70% of them come either from IITs or IISc Bangalore. It clearly indicates the lack of motivation of graduate students towards research in India [11].

4. ORGANISATION OF THE REPORT

This Chapter gives an overview of Engineering Education. It is also intended to articulate some general issues about engineering education before dealing with the changes required. It is also necessary to note in passing that while there are many defects in the existing system, there are also outstanding faculties with commitment in many remote colleges in the country. The Committee felt that the issues in Engineering Education can be addressed on the basis of ball-park estimates without getting bogged down by a search for exact statistical data. Although reasonably accurate data are indeed available in the literature [see Annexure 1]. Further it was felt that improving under graduate education will go a long way towards improving the health of the overall education system. So, detailed recommendations are made in this regard.

The rest of the report is organized as follows: Chapter II addresses the important issue of faculty shortage; Chapter III deals with teaching and learning; Chapter IV discusses the important issue of integrating science education with engineering education; Chapter V discusses Industry-Institute interaction and Chapter VI deals in passing with distance education recognizing that a separate task force has been set up to deal with this issue. Chapter VII addresses briefly the issues of regulation and governance.

CHAPTER 2 - FACULTY

1. INTRODUCTION

The single biggest challenge in the development of technical education at the moment is the dearth of qualified and motivated faculty. Teaching does not appear in the lists of priorities of engineering graduates in India. Most engineering colleges employ fresh graduates with no training or aptitude for teaching. The problem is compounded by the fact that most of the new comers to teaching have themselves been taught by indifferent teachers, and therefore, have no role-models to follow. There is virtually no training programme for teachers. Generally there are no teacher-training programmes in tertiary education worldwide, but most teachers in other countries join teaching after a few years of post-graduate school where they learn presentation and teaching skills by internship as teaching assistants.

Research and PhDs are pre-requisites for teachers in top-flight research institutions that supply man-power for research and for development of cutting-edge industry. But we also need a larger number of graduates to engage in manufacturing and field jobs. These students need quality education too, but of a different kind, for which the research capabilities of the teachers is irrelevant. Most engineering institutions are essentially undergraduate teaching colleges. What is more important in teachers in these institutions is the breadth of knowledge and understanding of what the industry needs. The bulk of engineering manpower even in the USA and Canada comes not from research universities, but from second-rung teaching institutions that do a very commendable job in their limited, but well-defined spheres.

India should utilise the talented, well educated persons in National Laboratories & Industries – though they may not have “taught” in colleges before.

2. MANPOWER MODEL

To understand the issues in all their varied dimensions we begin with an analysis of supply and demand for manpower in the engineering education system. The numbers have been rounded off to the nearest 100/1000 for convenience. These estimates are however adequate for making reasonable policy decisions.

How many graduates do we produce? Based on the statistics available, one can say that about 50% of PhD production is from the Indian Institutes of Technology (IITs) and Indian Institute of Science (IISc). At this level, the contribution at IITs/IISc M.Tech graduation rate is assumed to be about 60% of the sanctioned intake. IITs and IISc contribution is about 30%, that of state universities / colleges and National Institutes of Technology (NITs) about 30% and the remaining 40% coming from private engineering colleges which finance their expenditure from fees collected. B.Tech figures have been estimated under the assumption that overall graduation rate is around 60% of the sanctioned intake.

How many of these graduates are joining the engineering education pool? An educated guess is that 50% of the PhDs produced within IIT/IISc system join the academic manpower bank and the number for the rest is likely to be as high as 90%. In effect approximately 700 PhDs produced every year are being added to the academic sector. At M.Tech level, the percentage from IITs/IISc joining the academic sector may be as small as 5%, from the state universities/NITs the percentage joining the academic sector may be as high as 50%. It may be safe to assume that 95% of the M.Tech's produced in the private sector institutes become lecturers in engineering colleges. The total number of M.Tech's joining the engineering education pool is therefore approximately 8000. As far as B.Tech graduates are concerned about 10% of the graduates form the educational pool.

These figures should be compared with the needs of the engineering education system. The number of engineering degree granting institutions is about 1,500. About 10% of them can be considered to be research degree (PhD) granting. The number of institutions given permission to run M.Tech programmes by AICTE is 389 [12]. Therefore, the number of institutions where the highest degree programme is M.Tech is approximately 240.

If we assume that an average research degree granting institution has 5 engineering departments each, ideally, with faculty strength of 15 PhD degree holders, then the number of PhDs required in the system for meeting the needs of research universities will be 11,250. If we include the IITs/IISc then the figure can be estimated as 14,000.

In institutions where the highest degree awarded is M.Tech, under the assumption that ideally 50% of the faculty holds PhD degree and the rest M.Tech, the number of PhD and M.Tech degree holders required will be 9,000 each.

At institutions which only award B.Tech degrees, working with the assumption that there are only 4 engineering departments with 12 faculty each and 60% of them are M.Tech degree holders and the rest B.Tech, the numbers needed can be estimated as 32,000 and 21,000 M.Tech and B.Tech degree holders respectively. It must be stated that reflecting the requirement number of B.Tech degree holders should not be interpreted to indicate the desirability of fresh B.Tech degree holders to hold entry level teaching positions. Rather, it is just recognition of the state of affairs as it exists on the ground at present. Most if not all of them would be hired on ad hoc basis to fill positions for which qualified M.Tech degree holders are not immediately available. Those among them who would look upon academics as a career would be the ones who would work to upgrade their academic background by enrolling in M.Tech programmes. Recognising this need, some state technical universities have started experimenting with M.Tech programmes which are hybrids of distance as well as contacts during summer to upgrade the expertise of such faculty.

Therefore, the ball park estimates of the total number of PhD, M.Tech and B.Tech degree holders required in the engineering education system are 23000, 41000, and 21000 respectively. In this context it may be noted that the U R Rao Committee's estimates of the first two are 26000 and 30000 respectively.

Table 2 below summarises these numbers:

Table 2: Estimates of Supply and Demand for Teachers

Degree	No. of Engineering graduates per year from		Supply of teachers			Demand for teachers			
						in Institutions in which the highest degree awarded is			Total
	IITs	Others	From IITs/IISc	From Others	Total	PhD	M.Tech	B.Tech	
PhD	500	500	250	450	**700**	14000	9000	--	**23000**
M.Tech	4000	9000	200	7000	**8200**	--	9000	32000	**41000**
B.Tech	3500	250000	--	--	**25000**	--	--	21000	**21000**

The broad conclusions are as follows: The requirements of faculty at the bachelors' level are reasonably met. At the Master's level, approximately 8,000 faculties are added/upgraded every year. Since the system is geared to produce over 30,000 M.Techs every year, even the objective of all faculty members having at least an M.Tech degree at undergraduate engineering colleges is realisable in a fairly short period of time. However, it should be noticed that only about 3% of the M.Tech manpower in the system is being trained in our research universities. Over 60% have degrees from private engineering colleges. This skew will only increase with time. In essence the problem at this level is of quality and not of quantity.

PhD production in engineering in India has grown from a paltry 511 in 1982-83 to a still paltry 908 in 2003-04 suggesting doubling time of about 20 years [13]. Much of this increase is taking place due to rapid increase in PhD production at institutions where traditions of enforcing quality are not as high as at the major research institutes like IITs/IISc. The problem at this level is of both quality and quantity.

Hence the major issues in faculty recruitment and training are improving the quality of the M.Tech level manpower, and developing strategies for significantly increasing the rate of PhD production without compromising on quality. The first requires short term approaches which will continue to evolve on the basis of monitoring what works well and generation of new ideas to achieve specific sub-objectives that will arise in defining what quality means at that level. The second is a long term process which is more likely to be influenced by policy decisions taken at the governmental level.

3. Recommendations

3.1. Short Term Measures to Improve Quality

The purpose of improvement in quality of a faculty member is primarily to enhance the educational experience of the students. This improvement in training has two components: one is to ensure that B.Tech and M.Tech programmes are of better quality and are more rigorously conducted and the other is to focus on training of M.Tech graduates to improve their quality once they opt for an academic career. The first issue is addressed elsewhere in this report. The second is addressed below.

3.2. Quality Enhancement through Continuing Education in Distance Mode

Faculty members at undergraduate engineering colleges should be provided opportunity to enhance their knowledge and experience through coursework of a rigorous nature in distance mode. IITs and other select institutions should be encouraged to broadcast on Internet courses they are running on campus live, also digitise them, and put them on servers and have schemes under which faculty members in undergraduate colleges could register for a course. Those who have high bandwidth available can either listen to the lecture live or down load the lectures and view them at a convenient time. All other contact except examinations will be using chat and email. Laboratory exercises will be conducted using the equipment in the college. This would provide to a faculty member an opportunity to learn a new area in an environment which requires him to do all the homework and take the same exam that a student on campus does. Apart from the attractiveness of making available a high quality programmes to undergraduate faculty members at a distance and providing them an educational and learning experience that was missing in their formal education, the major benefit is that this gets done with very little additional cost in the IITs. The National Programme on Technology Enhanced Learning (NPTEL) of MHRD is a good beginning in this regard.

Even if the person who has undergone such training leaves the college where he is teaching because improved skills and knowledge base through the above processes gets him a job in industry, it must be noted that this up-gradation in ability would also have resulted in higher quality in his teaching at the college. The fact that teaching offers opportunities for such professional advancements would not go unnoticed. It would make teaching attractive and result in improved quality in the manpower pool from which teaching institutions draw their recruits.

The training programmes for teachers in non-research institutions have to be designed differently. There should be two approaches to Masters programmes, one for the research stream which may envisage a year-long thesis project (as is the norm in most institutions today), and the other for teaching, which should attempt to broaden the base with more courses, because that (and not specialization as represented by a PhD degree) is what that helps a teacher in an essentially teaching-institution.

Similarly, the short-term training programmes including the induction programmes conducted by Academic Staff Colleges set up by University Grant

Commission (UGC) should be modified away from the present content-independent model. We need to set up training programmes that teach teachers on what to include and how in such courses. National Institutes of Technical Teacher's Training & Research (NITTTRs) which were set up for this purpose are now essentially in the business of qualification improvement rather than quality improvement.

So far, only the theoretical courses have been considered for distance education. As laboratory experiments are a vital and integral part of engineering education, it becomes essential that mechanisms be developed to make the lab courses available online. MIT has developed online laboratories ("iLabs") as experimental setups that can be accessed through the Internet from a regular web browser. Around seven such labs were created which are being used by several thousand students across the globe. Another such example of remote laboratory is NetLab, which was developed and implemented at the University of South Australia (UniSA) in Adelaide, Australia. The distance laboratory course has been integrated into three undergraduate electrical and electronic engineering courses since 2003. It collects regular feedback responses from students, evaluate and modify the system in order to upgrade the quality of it.

However, it should be pointed out that Engineering of Science education is based on the hard rock of experimentation. While virtual experiments can be supplementary, these cannot replace actual experience in laboratories by the students and teachers.

3.3. Adjunct Faculty and Industrial Research Parks

A professionally active instructor through the process of interlacing the theory with real world engineering experience would motivate, enthuse and keep the student interest levels high. This can be done even more effectively by inviting professionals from industry and research laboratories to participate in the teaching process. Institutions should be encouraged to create adjunct positions for those professionals from outside the academia who would like to maintain a more permanent linkage with education. Benefits that accrue through the presence of adjunct professors beyond additional hands to teach are many. They range from opportunities for students to interact with professionals from industry, learn first hand issues involved in the practice of the profession, to opportunities for faculty to interact with industry and work on problems brought to their notice through interaction with the adjunct faculty.

Institutions near industrial hubs find it easier to involve professionals from industry in academic activities than those that are further away. To encourage interaction it is desirable that industrial parks be set up near a cluster of academic institutions. Big government funded academic institutions which traditionally have large campuses and have active research programmes should be encouraged to set up high-tech industrial research parks in the vicinity of their campuses. Easy availability of students, well established laboratories, faculty involved in research are attractions that have brought high technology research/product development initiatives to campuses in the developed world as well as to campuses in India which have experimented with this idea. Presence of such groups on or near campuses results not only in academic programmes that are more current, but also in new collaborative interdisciplinary research of relevance with greater potential for making an impact. Such environments also help in making the academic institution a more attractive place to work in and in the long run help attract as well as retain faculty.

3.4. Long Term Measures to Increase PhD Production

Over 50% of PhD graduates in engineering are from the IITs and IISc. Their number has remained essentially static during the last 20 years and the increase in PhD graduates is purely from institutions where quality enforcement standards are low. However, IITs and IISc have not reached their limits in PhD production. Like other major research universities in the West it should be possible for PhD output to be one per faculty member per year at these institutions. The fact that currently the average may be as low as one every four faculty members per year is primarily due to the unavailability of talented PhD students.

However, even a four-fold increase in current figures at these institutions, will make these graduates available only five years from now. Even if the numbers available to the academic system are projected optimally to be 700 per year, meeting the current shortfall of 23000 PhDs will take several years.

Not only do we need to increase the number of PhD students we need to increase the number of faculty members of good quality in the academic system. That the government is planning to open additional 8 more IITs is perhaps partly due to the recognition that we need more institutions where quality research manpower is produced. However, when the current pool of institutions is unable to recruit more PhD students and has about one third of the positions vacant, it is not clear as to where these new institutions will find faculty and research students of caliber similar to those currently in the IIT system.

This additional faculty will have to be recruited from abroad both out of researchers and academicians already well established with flourishing careers at senior levels, and fresh PhDs at the beginning of their careers. Our operating paradigms will have to undergo a profound change since the experience of the last fifty years tells us that our regular advertisements in papers do not generate the required response from scientists working abroad. To attract internationally competitive talent requires working environments and opportunities that are also globally competitive. Better salaries, modern infrastructure, responsive bureaucracy, better living conditions should be provided. All that is required to enable them are additional finance and facilitating management practices. However, all this will also need to be supported by an assured supply of large number of research scholars of good quality. Large vibrant PhD programmes alone will attract good students who now go abroad for doing their PhDs.

In recent years there is a noticeable drop in the number of students going to USA for graduate education. International careers with large financial compensation have been available without going through the U.S. graduate school route. The net for finding good quality graduate students will therefore need to be spread wider. Pro-actively identifying talent among those students who are outside the well-oiled system is essential. Such talent should be nurtured with opportunities for international exposure during the formative stages of their doctoral studies. This international exposure can take many forms the easiest being assured regular attendances at international conferences. However, one needs to do much more. Putting in place systems that enable a research student to spend about one fourth to one third of the time at the work place of the supervisor's international collaborators will be a significant attraction. If one budgets $20,000 or Rs 8 lakhs per student then Rs 100 crores per year will support 1,200 students every year.

A similar scheme which enables a faculty member to spend two months per year working at the site of his international collaborator also needs to be put in place. Expenses per faculty member per year will be around $10,000. Rs 100 crores per year will support 2,400 faculty members. Considering that setting up expenses of a new IIT over a period of 5 years are likely to be at least Rs 200 crores a year, impact of the likely increases in salaries and student stipends in the IITs/IISc system to cost the exchequer additional Rs 300 crores a year, costs of implementing the proposed schemes will not increase the additional expenditure already being planned for by more than 10%. These schemes are feasible. They are a crucial part of the systemic change required in our mind sets which needs to become researcher centric rather than just procedure and infrastructure centric. This change in our mind set and approach is perhaps more important than any number of well thought out schemes. Without this change in place, even with the best of intentions, all the budgeted expenditure will not result in desired end objectives. That is the biggest challenge.

3.5. Professional development of the faculty

This aspect has assumed serious proportion. The need for making academic and teaching profession attractive is very high. Unlike the 60s to 90s, the best students are not considering this career due to the skew in compensation and opportunities driven by market situation.

In order to address this, a different model has to be adopted; this is to select such of those who are reasonably good and have a passion for teaching from UGs. Invest in them by way of providing rich content, pedagogy and opportunity to improve their academic qualification by creating opportunities for further studies. This can be an on-the-job opportunity;

Some degree of deconstruction of the job of a top notch academic will help in restructuring the professional needs of educational institutions to address the problem. For example, in institutes of higher learning abroad, the graduate students assist the professor in creating new learning aids, teaching laboratories, setting question papers and correction. In this mode the student learns valuable lessons in education while providing more time to the professor for his research.

3.6. Teacher Training

A one-day regional workshop on teaching/learning processes by carefully identified good teachers and by educational technology experts should be arranged atleast once a year as part of the academic calendar. The workshop should focus on one or two aspects of teaching as an aid to improving the quality of education.

Teacher induction training dealing with the basics should be insisted upon for anyone who wants to be an engineering teacher. This could be a two weeks contact course conducted by senior mentoring faculty at the national level. It might be advisable that NPTEL also puts up such teacher training courses for those who can not attend such in-person programmes. Subsequent periodic refresher courses should be organized.

3.7. Quality Enhancement through Secondment to Industry

It is well established that undergraduate teaching environment in university colleges and/or engineering institutions, at present, does not offer career options that are attractive enough in comparison to industry. Undergraduate degree granting institutions do not offer opportunities for research, the primary reason for institutions like IITs to hold on to their faculty and recruit new ones. What then would attract a good well trained person to an undergraduate teaching career? One possibility is to provide opportunities to grow professionally through secondment to industry.

The idea is that during these secondments, which could take place during summer holidays, a faculty member will work like an apprentice engineer and improve his practical skills. These improved practical skills will have positive impact on both the classroom as well as laboratory activities. Other benefits also get accrued. A relationship with an industrial unit gets established. Faculty members can bring back development work and carry it out in their colleges involving students. Opportunities for consulting develop. They add to income, but more importantly they add to self esteem. Teaching starts providing opportunities to grow. Even if a person leaves to join industry, the possibility to do so will be an attraction for others to join.

Bringing this activity under the apprenticeship act may be one of the ways which could facilitate effective implementation of this activity.

CHAPTER 3 - TEACHING LEARNING PROCESSES

1. INTRODUCTION

World wide trends in engineering education stem from the nature of engineering as it is practiced today in the globalized world:

- All institutions should adopt the credit-based semester system of education
- Academic credits should be assigned for various activities laboratory / design / co/extra curricular activity / theory and corresponding contact hours should ensure that students pay enough attention to all the segments.
- Teaching emphasis is no longer on memorizing facts but on finding, evaluating, and using information.
- Significant amount of course time is now devoted to discovery-based (which includes project-based) learning over traditional lecture modes of transmitting knowledge.
- Course content is interdisciplinary and interdepartmental.
- More collaborative work in diverse groups.
- Teaching and learning extend beyond the classroom and into the community.
- There is more emphasis on transferable skills (like problem solving, and interdisciplinary teamwork) over encyclopedic knowledge.

With so many conflicting requirements and diversity in philosophy of educational institutions, a single solution can not be proposed for the delivery and pedagogy for courses and syllabi. A pragmatic approach is to identify the strengths and weaknesses of each type of academic institution and make suitable adjustments / recommendations. Not withstanding the changed scenario in the past couple of decades, insistence on basic, sound engineering and applied science fundamentals is extremely important. This should be the core and invariant component across all the institutions.

Teacher should concentrate on teaching concepts and application of these towards problem solving. Additional skill sets necessary for modern day engineer should be integrated as part of some of the subjects and not taught as separate courses. For example, project management or communication and presentation skills should be integrated into some or all courses. Industry participation to discuss real life case studies should be encouraged. Term papers, seminar presentations should be made compulsory (with certain weightage attached to it) in most of the semesters. While retaining similar contact hours, the component related to the teacher-centric mode should reduce and self-learning mode of the student should be enhanced during later semesters. Senior faculty mentoring while a junior faculty is teaching a subject could be tried out where possible. Continuous training of teachers is required. Teacher evaluation and course evaluations should be conducted scientifically and the results should be made public for greater accountability.

In the absence of complete student mobility across institutions due to regulatory structures, at least credit transfer amongst pre-designated institutions should be permitted. Summer / winter vacation courses should be offered to facilitate and widen the coverage area. Calendar for these should be widely publicized ahead of time.

The role of many colleges is primarily for teaching relevant knowledge and skills well and not for research. For all these colleges there is a need to have 3 months course of practical professional English – speaking, writing and reading. Consultancy and research are secondary. There is a disproportionately large number of credits assigned to the final year UG project done by the student. It should not be more than that for one or two theory subjects. With increased student strength, it is rather difficult to ensure seriousness and quality of project work and thus justify such lopsided academic weightage.

2. OBJECTIVES OF THE PROGRAMME

To educate and prepare students for a variety of challenging careers in

- industry: production, service, R & D and design sectors
- higher education in engineering and management
- software development for applications in engineering and technology

2.1. Desirable characteristics of an Engineering Graduate

- Sound knowledge of the fundamentals
- Reasonable familiarity with computers and computational aids and numerical techniques and simulation
- Ability to carry out the design process from problem definition to solution
- Ability to gather pertinent information and deal with incomplete problem definition and interdisciplinary constraints involving safety, aesthetics, reliability, economics, politics, ecology, law and sociology
- Ability to visualise and reduce data, concepts and designs to clear pictorial forms
- Ability to find approximate solutions by making reasonable engineering assumptions when required
- A well-developed sense of engineering ethics and principles that help in making moral choices in the professional context.
- A strong commitment to national development through the use of technology consistent with social justice.
- A high degree of self-confidence for well-informed decision-making
- An ability to work individually and as part of a team

- Effective oral and written communication skills

2.2. The B.Tech Programme [14]

A well-defined Knowledge component consisting of coursework relating to

- a major professional area of specialisation
- a minor interdisciplinary area
- basic engineering sciences
- physics, chemistry and mathematics
- humanities, social sciences and management
- topics of current socio-economic relevance

A know-how imparting component consisting of :

- Laboratory courses
- Skill development in use of equipment and instruments
- Project work
- Industrial training, exposure to real-life problems and team work
- Opportunities for individual initiatives such as participation in research, seminars or design competitions

A character-building component that includes:

- Professional Society activities
- Co-curricular and Extracurricular activities
- A case-studies-discussion course in engineering ethics

3. STRUCTURE & CONTENT

The B.Tech programme should be broad-based, be credit-based with continuous evaluation, emphasize fundamentals, offer flexibility in course-work through electives and include an NSS/NSO/NCC with no credit assigned. Recommended unit of instruction is a semester which can be considered to be equivalent of 16 weeks of instruction. If one lecture hour, one tutorial hour, and two hours of a laboratory session per week are assigned one credit then the total credits for a four year B.Tech degree programme should be around 180. This figure is arrived working with the assumption that students register for about 22 credits per semester distributed over 5 courses. The table below recommends minimum percentage credits for different categories in the curriculum. These are only guide-lines and each university should continue to be free to devise its own curriculum.

Category	% of Total Credits
Humanities and Social Sciences	**10**
Basic sciences	**12**
Mathematics	**8**
Basic Engineering	**10**
Engineering Skills	**5**
Professional Lab.	**10**
Programme Core	**30**
Minor including Management	**6**
Industrial training	**1**
Electives	**5**
Project	**3**

Total Credits[@] For A B.Tech Degree 180

[@] A semester is equivalent to sixteen weeks of instruction. One lecture or tutorial hour or 2 laboratory hours per week per semester is assigned one credit.

Table 3: Credit Distribution in Curriculum

- A flavour of engineering should be given in the first semester itself. The standard of the science curriculum at the plus two levels is sufficiently high for many of the engineering courses to be taught even in the first few semesters. This means that the students can come into direct contact with the chosen major engineering disciplines and their courses of study in the very first semester to give them a flavour of engineering.
- Mathematics, Physics and Chemistry courses should avoid unnecessary repetition of material covered at the plus 2 level. Departments should have the flexibility to choose a combination of courses in physics and chemistry subject to a minimum in each. At least one of the Humanities courses should concentrate on developing oral and written communication skills. One of the big differences between our graduates and those from the good schools in the West lies in the superior ability of the latter to communicate precisely and effectively especially on professional topics.

- One course should be on Current Topics of social or industrial or national relevance with lectures on topics (these should be changed as often as required) like Intellectual property rights, Biodiversity issues, Technology for sustainable development. Lectures can be given by invited speakers and several faculty.
- It is important to educate the student in an interdisciplinary area of current interest outside his/her major area of study. This is conveniently done through a minor stream chosen after the 3rd semester. It should consist of a sequence of courses in an interdisciplinary area of current interest in technology, science, humanities or management together with pre-requisite courses. Some possible minor streams are: Nano Science and Technology, Environmental Engineering, Software Engineering, Manufacturing Engineering, Information Technology, Dynamics of Non-linear Systems, Sustainable Development. Students should be encouraged to choose minor areas based solely on their interests.
- Self-study: At least one course in the major category should be designed for self-study after the fifth semester in order to encourage students to study a prescribed text-book and learn on their own without the benefit of formal lectures. The teacher should only serve as a facilitator. These courses should be divided into at least five topics with at least 1 test per topic in a semester in order to gauge the progress of the students. Grades should be based on the marks obtained in all the tests.
- Laboratory courses should be revamped taking into account the following guidelines:
    - Students should acquire a familiarity with the operation of equipment with an appreciation of safety and learn the techniques of accurate measurement.
    - Students learn more from fewer experiments with more detail carried out thoroughly than from many experiments done in a hurried manner.
    - It is not necessary for every student to do every experiment. Selected sets can be assigned to each student. Faculty teaching the theory should be involved in the design and execution of the experiments.
- A 6-weeks (minimum) Industrial training should be planned and executed in the industry with faculty supervision and should carry some credits. Every student should submit a comprehensive report and present it before the UG committee. Group discussion should be arranged on each project and the students ability to participate meaningfully should be counted towards the final grade. Students should be encouraged to come up with a suitable problem definition that is relevant to the industry and forms the basis of his/her project. The grading will be done on the basis of a weighted sum of marks given by the training officer in the industry and the faculty supervisor. This training, if designed and implemented carefully, can be a learning experience that helps in building self-confidence in the student.

- As far as possible, the project should focus on good professional practice in design. The importance of good documentation and good oral presentation must be impressed on the students by insisting on adherence to well articulated instructions on the presentation of the project report.
- The engineering skills category includes workshop and drawing. Both need complete revamping of contents to teach modern techniques in place of conventional outdated practices. Meanwhile the courses should provide for more than training in skills and should be able to encourage creativity. For example at least some assignments should focus on creation of designs that satisfy a need rather than on making pre-specified shapes and sizes.
- Students will be able to opt for a mini-project in open ended design (with emphasis on synthesis as opposed to analysis in lieu of one 3-credit course.
- In evaluating the performance of the group and the individual in particular, in a given/set "Project", soft skills and communication skills must find appropriate mention, as a part of the desired outcomes, assessed and evaluated (self and peer evaluation). In the ever evolving globalize work environment that are young engineers find themselves in, an astute ability to judge, respond and communicate information and ideas appropriately with a good mix of interpersonal skills may spell the difference between success or failure. Creating the correct degree of awareness and building capacity in that direction would require the requisite allocation of value in the portfolio of assessments and in the award of learning attained.

3.1. RELATED ISSUES

- Course type and Performance Evaluation: Courses should be broadly classified into four broad types as indicated in the table below. A balanced curriculum should contain courses of all types. Each teacher should have the freedom to determine the method of performance evaluation best-suited for the course in consultation with the students. It is imperative however that this is finalised and unambiguously explained and spelt out to the class by the end of the second week after the beginning of instruction.

Types of Courses

Type	Components	Evaluation Components	ET classification
A	Lectures	Tests/Assignments	Teacher-centered/lead
B	Lectures	Tests/Assignments/Group discussions	

C	Laboratory	Tests/Performance in class	□
D	Project	Quality/ Report/ Oral presentation	□
E	Self-study	5 or more periodical tests	Student-centred

- An Academic Honour code should be introduced**.** In order to build character and improve the levels of honesty and integrity in the classroom and outside, the student body should be persuaded to adopt the principle that all academic activities will be based on a well articulated code of academic honour. The Students should accept responsibility, individually and collectively, to maintain and perpetuate the principle of academic honour. The principle should attempt to uphold intellectual honesty and integrity in the class and outside and will provide for severe punishments commensurate with the offence. For a sufficiently severe violation of the honour code the student will have to forfeit the opportunity to continue his or her education. Each student should, at the time of enrolment at the beginning of each semester, sign the honour code accepting his or her responsibility in the matter.
- Teachers should be encouraged to use audio-visual aids including computers in the classrooms to improve communication between them and the students. At least a few modern class-rooms should be set-up in each department. Videotaped feed-back should be provided to help faculty improve their teaching methods.
- The credit-system should be adopted uniformly together with continuous evaluation and a well-articulated system of relative grading.

3.2. LABORATORY EDUCATION

The primary objective of laboratory instruction is the development of abilities to plan, design, conduct and report experiments through data acquisition, analysis and interpretation. Further, laboratories can also be used to develop attitudes, values, habits and professional skills through experimental and collaborative learning.

Undergraduate laboratories are perhaps the weakest links in the chain of engineering education. Everyone from the student to the administrator seems convinced of the need for the teaching laboratories but nobody appears to be satisfied with them. The students view laboratories as boring, not intellectually challenging but involving a lot of cookbook style chores. The equipment seems outdated. To a teacher, laboratory teaching is a second-rate job that does not contribute to his professional development. It is largely boring and repetitive and to which the students are completely apathetic. The college administrators view laboratories as perennial sinks of money, and as sources of administrative and employee problems.

The problem arises from the fact that there is a lot of confusion about the design and conduct of experiments. It is wrongly believed that more the number of experiments, the more is the ‘practical' learning. Most of the experiments in undergraduate labs are fully-set experiments where detailed instructions are given to the student. Just like all other courses there is no opportunity for exploration in the lab courses as well. A student walks up to a set-up, turns it on, takes a few readings, and walks away to write a detailed report. At best an experiment is just a numerical problem with realistic data.

Table 4 gives some of the possible specific aims of the laboratory instructions as deducted from diverse sources. It must be realized that most of these aims are at the lowest cognitive levels, and do not contribute to education of an engineer. An engineer conducts experiments for essentially one aim - to obtain data for design. The present conceptualization of the undergraduate teaching labs does not even attempt to address the issue.

Table 4: Some Possible Aims of Laboratory Teaching

Familiarization with	Standard equipment Measuring technique
Illustration of	Physical Phenomenon Concept taught in lectures
Teaching of	Attitude to experimental work
Providing	Closer contact with faculty Stimulation to independent thinking Feel for R&D labs
Training in	Observation* Deductions from observation* Critical awareness* Keeping lab note book Writing reports Acquiring specific information

If properly designed, the following professional competencies can be developed and enhanced through the laboratories:

- Technical competence in usage of tools and techniques.
- Experimental research skills.
- Creativity and design skills.
- Decision making skills.
- Attentiveness to details and critical thinking.
- Integrity, authenticity, accountability and responsibility.

- System level perspective, user orientation and entrepreneurship.
- Group work, mentoring, leadership and multitasking.
- Quality Consciousness and pursuit of excellence.
- Perseverance and spirit of inquiry.

A major problem with all laboratory experiments is that they do not attempt to challenge the student sufficiently and the whole exercise is conducted at a very rudimentary level. Vital aspects of experiments are not highlighted for the students. The student is typically not involved in such vital aspects as designing or selecting the apparatus, what measurements need to be taken, or what variables need to be controlled. In fact, a student has no control over the experiment, including how the tests are to be conducted or how the accuracy is to be estimated. Students are given no opportunity to think for themselves.

Design of Lab Courses

The following may be used as the guiding principles for design of laboratory courses:

- Lab experiment should not be laid out completely. There must be decisions that a student has to make.
- The purpose of an experiment in a lab course is to teach a student the experimental method. For this purpose, give minimum of directions. The student should gain control of the decisions that are made while conducting experiment. The student should choose the unique parameters of the experiment.
- Experiments should not be just demonstration, or verify the law type. They must involve collecting data for design, or using principles to design gauges, or investigating a new situation.
- Error analysis, up to and including calculation of error bars should be essential requirement for each experiment.
- Each experiment should be so designed that it takes up the full assigned time.
- Student should be taught how to keep a lab record book.
- Students should not be required to write up reports on each experiment. For most experiments it should be the lab record book that should suffice. Training may include maintaining lab journal.
- Students should be taught technical communication skills in lab courses. This may be done by asking students to write up some experiments (one or two) as a Technical Note to a standard Journal using the format specified by that Journal. This would need feedback from the instructor and may be done in two steps: first a draft report is submitted which is discussed with the students, who then revise and resubmit the same.

Some of the concerns about the general undergraduate engineering educational experience are that it is bookish, is devoid of practical engineering and design issues, it does not enhance problem solving skills, and, consequently, it does not generate among the students any sense of identification with the professions involved.

What really distinguishes a good institution from a bad one is the quality of the laboratory and project work. One step that will have a very positive impact on quality is improvement in the laboratory work. This requires availability of good laboratory manuals and case studies. While there is no shortage of good theory textbooks there is no tradition of publishing and disseminating laboratory/project case studies. In the West, the instructors are supposed to be and often are innovative in this regard and generate their own material. We need to create a tradition of recognising innovation in laboratory experience, reward it and create opportunity for sharing and disseminating it. One could begin collecting faculty experts from recognised good institutions in focused areas, and having them contribute one or two of their laboratory/project exercises that they have found have worked especially well with students. This collection, which contains the experience of conducting these exercises in all details, would serve the purposes of setting standards to emulate and also provide the required initial hand holding. To create a tradition of innovation and encourage and reward it forum would need to be created where faculty members in engineering colleges report their experiences. If a reported case study of an innovative project/laboratory exercise coming out of an undergraduate college is considered to be as meritorious an activity as a quality research publication out of a research institution, there are every reasons to believe that faculty members in undergraduate colleges will work towards creating them.

It should be noted that good laboratory environment improves confidence as well as motivation, among students as well as instructors. Classroom teaching improves as it is possible for the instructor to relate it to what is happening in the laboratory, and for the student to understand the concepts intuitively having experienced the issues first hand.

3.3. Workshop in the B.Tech Curriculum

It is a well established fact that workshop practice offers opportunities for students to learn many practical skills. Traditionally, workshop has emphasized more of "drill" than real experience with the “World of Engineering Practice". While drill is essential for students to pick up a minimum level of skill in dealing with the tools used in the basic shaping of materials, knowledge about how things are put together in practice should be given greater importance. Some sessions may be replaced by demonstrations or special video presentations.

The curriculum relating to Workshop should provide for the following:

- Impart training on Basic Tools used in Carpentry and Fitting. The experience gained with such tools should allow the student to properly handle the tools. Reading material on the concept and usage of these tools should be provided where additional information about specific uses may be given. Students should be taught the standard terminology used in specifying tools.

- Introduce students to the tools and techniques of Assembly and Manufacturing. The idea behind this is to expose the student to the methods and components used to put together an item or product. Examples from Mechanical Engineering, Electrical Engineering and Electronics may be effectively used to illustrate the principles.
- Give the students additional information about the "Manufacturing Process" through short films, video presentations.
- Expose the students to the different techniques of measurement of mechanical, electrical and other physical quantities. Specifically introduce them to the concept of accuracy and tolerance in measurements.
- Provide facilities for students to design and fabricate small items to do specific jobs. For example, a robot may be designed and controlled using Electronic Circuits or Computer interfaces.
- Introduce the students to the concept of equipment control using Electronic Circuits and Computers.
- Couple the syllabus of Workshop and drawing so that students appreciate the need to present assembly information through carefully produced drawings. The curriculum for drawing should be revised to include Computer based drafting and projections of assemblies.
- About 30% of the time specified may be devoted to students experimenting with fabrication and assembly.
- Introduce the students to the concept of safety while working with equipment and tools. It would be very useful to have specific manuals for important equipment. Simple items of information such as Power handled, Cutting forces etc. would allow students to estimate the requirements for installing the equipment.
- Often toys can be used to illustrate the engineering principle behind an implementation. Some of the exercises could well be on building some toys.

Workshop should be given in the first two semesters. It should therefore be possible for some students to take a third semester of Workshop as an elective. The students should be tested on what they have learnt and not be given a purely practical test. Examinations requiring much physical labour should be avoided. A written or oral examination to test the student's knowledge of the concepts learned is desirable.

4. CO-CURRICULAR ACTIVITIES

Co-curricular activities are academically oriented programmes complementary to the formal curriculum augmenting the learning process in a non formal environment. Although voluntary in nature, students at all levels must be encouraged/ motivated/ persuaded to participate actively in such activities during their free time Departments. And the faculty should come forward to assist the students in all possible manners, as co-curricular activities improve the knowledge base, encourage creativity and team spirit, promote healthy competition and lead to a sense of achievement.

- The institute must generate opportunities for the students to actively engage in co-curricular activities. Departmental associations and student chapters of professions bodies have a major role to play in this matter. Such associations must be started if they don't already exist.
- Associations should organise competitions, lectures by experts in the field, take part in competitions arranged by other institutions, industrial visits etc. The scope of these activities can be widened to include students of sister institutions in the locality to start with and the region, at a later stage.
- Annual inter-institutional competitions in co-curricular activities must be initiated and coordinated by rotation. Federation of Indian Chambers of Commerce and Industry (FICCI) or CII may be approached to sponsor these annual events.
- Honour Societies where one earns a membership by selection for his/her contribution to co-curricular activities should be started. Such membership must add to the prestige of the Individual.
- Innovations need not always be high-tech. There could be a number of innovative solutions to every day problems of our society and such activities also should be encouraged. Sufficient avenues must be provided to students to try out innovative ideas after an initial scrutiny. A well-equipped Hobby workshop should be set-up for this purpose.
- Recognition at appropriate levels can stimulate student interest in co-curricular activities: Cash awards, publicity in Campus publications and press depending on the level of achievement can go a long way in encouraging these activities. Achievements in co-curricular activities can be recorded in the appropriate space provided on the back of the Grade card. The very provision of a space for such entries will pressurize students into participating in such activities.
- An Advisor (Co-curricular) may be appointed for this purpose. A committee of faculty convenors and secretaries of departmental associations and student chapters of professional bodies as members may be formed to draw up a schedule and implement the programme every year. A Co-curricular affairs student secretary must be elected and given the overall responsibility for organising intra-institute competitions.

5. TEACHER-STUDENT & STUDENT-STUDENT RELATIONSHIP

Building human relationships is an important part of a student's education. The university can

- provide forums for Teachers and Students to interact with each other outside the classroom.

- encourage the community to discuss and talk about matters of relevance and importance through campus periodicals and publications.
- inculcate team spirit among all those involved and generate campus activities that require people to work together to achieve any meaningful result.
- identify faculty who will willingly provide their time to discuss matters relating to teacher-student relations and counsel and interact with students on general matters. This requires a definite commitment on the part of the faculty (much like the commitment of hostel wardens), and hence cannot be forced on any individual.
- arrange a monthly meeting of the community where general student matters are discussed. As a rule some general issue of interest to everybody should also be included.
- have regular meetings of technically minded people who can discuss and suggest solutions to the ills of the Campus resulting from mediocre approaches to providing technical amenities in the campus.
- give responsibilities to students in managing some departmental affairs. eg. A student library and a computing facility that is open throughout the day.
- encourage good writing through campus publications where people regularly air their views. Take these views seriously and avoid censorship. Often these publications can act as mirrors and also highlight special achievements of the campus community.
- form Design Groups with students and teachers so that they can take up some activity during vacation and come up with some useful facilities for the Institute in innovative ways.

6. TEACHER EVALUATION/PERFORMANCE FEEDBACK

Measures taken to evaluate a teacher's performance and to promote the effectiveness of his/her teaching merit the attention of all concerned. Feedback information is intended to broadly serve the following purposes.

- To enable the teacher to know his/her strengths and deficiencies and use feedback information to improve his teaching.
- To give to the Head of the Department and the authorities of the Institute an indication of what the students feel about the performance of the faculty member as a teacher.

In spite of inherent deficiencies, the exercise of student feedback and evaluation is an important and necessary one. The feedback forms for theory and laboratory courses should be designed differently. Sample forms are given in the annexure of this chapter. A word of caution is in order: The feedback should be treated as part of an evolving process of relationship between teachers and students till the institution matures. These forms should be computerized for easy access, analysis and storage.

Feedback on theory Courses

Semester:

To The Respondent

The objective of this questionnaire is to provide constructive feedback for improving teaching effectiveness. Your responses will assist the teachers and the departments in their endeavors to strengthen all aspects of this course.

For the results to be most useful, your responses should:

- be as objective and sincere as possible
- be based on your own individual thinking
- be based on overall performance rather than on impressions gained through isolated incidents.
- consider each question independently, without being influenced by your other answers.

Course and Teacher Information

i) Course No: ______________ iii) Teacher's Name: _______________

ii) Course Title: ______________ iv) Class size: ____________________

FEEDBACK INFORMATION ON TEACHING

	YES	NO	NA*
1. Course contents were clearly specified at the commencement of the term and were adequately covered:	☐	☐	☐
2. The teacher spoke clearly, audibly and directly to the class:	☐	☐	☐
3. The teacher had good organisation on the blackboard and the writing was legible:	☐	☐	☐
4. The lectures were well-paced:	☐	☐	☐
5. The teacher effectively used examples and illustrations to help clarify the subject:	☐	☐	☐
6. The teacher organised the tutorials effectively:	☐	☐	☐
7. Exam. questions were clear and free from ambiguity:	☐	☐	☐
8. Evaluation was fair and impartial:	☐	☐	☐
9. The tests were graded and returned within a reasonable time:	☐	☐	☐
10. The tests and examinations were discussed adequately upon return:	☐	☐	☐

*** Not applicable**

FEEDBACK INFORMATION ON INSTRUCTION

A = Excellent; B = Good; C = Satisfactory; D = Marginal; E = Poor; F = Unable to express an opinion

	A	B	C	D	E	F
1. Course planning and organisation:	☐	☐	☐	☐	☐	☐
2. Preparation for the lectures:	☐	☐	☐	☐	☐	☐
3. Overall communication:	☐	☐	☐	☐	☐	☐
4. Explanation of difficult concepts:	☐	☐	☐	☐	☐	☐
5. Providing motivation in the subject:	☐	☐	☐	☐	☐	☐
6. Interest in the students and their progress:	☐	☐	☐	☐	☐	☐
OVERALL RATING OF THE TEACHER	☐	☐	☐	☐	☐	☐

Feedback Information on Laboratory Courses

A = Excellent ; B = Good ; C = Satisfactory ; D = Marginal ;
E = Poor ; F = Unable to decide / Not applicable

Facilities]

1. Condition and availability of equipment needed for experiments

Experiments

2. Usefulness of the experiments in clarifying/ deepening your knowledge of the theoretical concepts and in providing additional knowledge

3. Usefulness of the experiments in your learning new experimental techniques and familiarising yourself with new instruments/ systems

Supervision

4. Preparation of the group of teachers for the supervision of the experiments

5. Usefulness of laboratory instructions (in oral/ in written form)

6. Help provided by the teachers in your understanding the experimental observations and in explaining the difficulties that may have arisen in the experiments

Overall

7. Your overall rating of

(a) this particular laboratory course

(b) the team of supervising teachers?

Add general comments on what you feel about the laboratory course and how it can be made more useful. You may also comment on whether and where there is scope for more individual initiative (more open-ended experiments) and indicate, giving reasons, experiments which can perhaps be modified, dropped etc.

7. EVALUATION

7.1. Introduction:

Faculty should have the freedom to experiment with the evaluation systems. It is however possible to provide guidelines for evaluation especially in large classes.

7.2. Current evaluation system:

The typical university system has minor variations of the following practice:

Theory

- The final exam carries 100% of the marks
- Examination carries 80 marks and in-semester evaluation carries 20 marks
- In all examination papers, there is generally a choice e.g. “solve 5 questions out of 8 questions”.
- The pattern of the question paper is set one. Rote learning and memory are amply rewarded.
- Corrections of papers are generally done at predetermined central places in a prescribed time (usually eight days). The faculty who correct the papers of the subject need not have taught the subject.

The major problems with the above system are:

- Errors in assessment due to overwork and lack of familiarity with the subject.
- Options available in the question paper, lead to students guessing “topics likely to be examined” and scoring 90% with knowledge of only 50% of the course. .
- Students are generally given cent percent marks for in-semester performance and just scoring about 20-30 % marks in final paper is adequate to pass the course.

7.3. Continuous Evaluation:

It is generally agreed that students should be evaluated “continuously” and transparently through:

- Home assignments
- Class tests, Quizzes (Long notice, short notice, surprise)
- Project work (Minor and/or Major, either group/or individual activity)
- Mid semester examinations (one or two)
- End semester examination (generally carrying about 50% of total marks)

The system should ideally provide multiple chances for the student to improve the grade/marks, use of different evaluation procedure for fast learners and slow learners and giving more importance to understanding the concepts rather than to rote learning.

It is desirable that the performance evaluation be grade based rather than on absolute marks. Grades allow the possibility of reflecting in them a combination of relative and absolute performance. Also, grades normalise over different instructors, toughness of the question papers, and variations in the quality of assessment within a course. They are better indicators for comparison in case comparisons need to be made for any of a variety of reasons.

The process of continuous evaluation implies that the primary responsibility for testing and evaluation lies with the instructor for the specific course he/she is teaching to a set of students. There are other very sound reasons for making the instructor responsible for all assessment. Only such totally decentralised systems can be open. They enable students to see the evaluated answer scripts and understand the mistakes they have made. Examinations then become a part of the learning process not just the medium by which learning or lack of it is established periodically.

Inherent in this is the realisation that we need to shift away from the current system where conduct of the examinations is one of the primary duties of the university. One of the primary reasons why semester system, credit based student progress is not popular with the universities is that conducting examinations at the same time and date at a large number of centres for a large number of subjects is a major time consuming organisational task which universities cannot afford to do very often. The task is so stupendous that conduct of examination and declaration of results in time and regularly is considered to be the biggest indicator of a well run university. That the syllabi are out of date and were last modified twenty years ago would not be the reasons for a Vice Chancellor to loose sleep as long as the examinations were being conducted on time.

Moving to semester system, making the instructor responsible and accountable for conduct of a course in all aspects ranging from lecturing, assigning homeworks, conducting quizzes, holding mid term and end of term examinations to evaluation and grading are the first steps towards academic autonomy not the one of the by products of that process.

While setting a question paper care must be taken to address the entire range in the Taxonomy of Thinking/Learning skills. Higher order thinking skills must find appropriate value allotment, with reference to marks provided. Moreover, to frame appropriate questions to elicit the plethora of desired outcomes requires horning one’s skills in setting a paper with the right frame, words and sentence structure.

8. Counseling and Placement Issues

Following the rapid expansion of enrolment in engineering education over the past decade or so, most states have sought to regulate this by setting up one or more Technology Universities for the State. Given the rapid changes in our society the family support structure for students has been under severe strain. There is a clear need for counseling of the students. Rough estimates indicate that as many as 50% need some kind of psychological counseling and 25% need immediate attention [15].

The causes can be traced to increased anxiety level caused by failure to live upto the parental expectation and failure to survive peer pressure.

Freshmen need to deal with change in environment, perceived expectation and insecurity while graduating students need guidance both in how to prepare for the placement as well to handle the stress of a failure. They need to reorganize their own aptitude and limits of their capability. In between it is a mentoring system.

Engineering education has two distinct issues to deal with : For preparing 'industry ready students' a Training and Placement Cell has to be organized and a number of training programs for the students of all semesters needs to be introduced with the help of in-house experts and experts drawn from professional agencies. The staff members of the placement cell must work as a team in molding students through well organized career guidance programs, reasoning tests, aptitude tests, puzzle solving, group discussions, mock interviews, brain storming sessions, case-discussion, pick and speak, sharing the experiences and communication skills. One specific aspect of HRD training would be to motivate and develop the personality of students.

CHAPTER 4 - INTEGRATING SCIENCE AND ENGINEERING EDUCATION

1. SCIENCE AND ENGINEERING EDUCATION

Although the Committee was set up for Engineering Education, it is difficult to think about Engineering Education without thinking about Science Education. Today, technology pushes the frontiers of science further and science, in turn, is opening new doors for technological innovation.

The soundness of science based engineering education that was introduced by the IITs in 1960's in India has been vindicated by the success of IIT graduates in the subsequent decades. Analytically trained minds became the success stories globally. Until 1980's students took five years to complete undergraduate engineering (B.E./B.Tech) education and undergraduate medical (MBBS) education. Their colleagues pursuing science took invariably (3+2 =) 5 years to obtain a Masters degree. By 1980, B.Tech became a 4 year programme, while Masters of Science (M.Sc.) continues to be a 5 year programme the 3 + 2 model in universities or the 5 year integrated Master's programme in some IITs. The choice in front of a student coming out of a 10 + 2 programme from school was clear. The option to go for a 4 year programme in engineering that promises a job even before graduation was irresistible, when compared to a 5 year programme that did not promise a job.

For decades, the United States has had a four year undergraduate programme in which there is hardly any distinction between science and engineering education. In India, the distinction became stronger. While the American education system provided enormous flexibility and permitted cross migration between disciplines, the Indian education system became more compartmentalized. Despite a lot of lip service, switching between science and engineering streams has become about impossible.

Keeping in mind the emerging areas of science and technology, particularly in smart materials, nanomaterials, micro (molecular) electronics, biotechnologies, biosensors, etc, it is increasingly clear that the distinctions between science and engineering are artificial. It is therefore extremely important consider starting broad based science undergraduate programmes along the lines of four year engineering programmes. One of the advantages would be that this would provide enough flexibility in our undergraduate curriculum, to allow students to switch between different areas of science and technology and between institutions with appropriate transfer of credits. One could experiment with such possibilities of transfer of credits initially by starting such programmes at some select engineering institutions. The IITs (and the newly started Indian Institutes of Science Education and Research (IISERs)) are the natural places for such initial experimentation. Success of such experiments and the experience gained thereof may be the basis for its adoption on a much wider scale in our educational system.

The advantage of such a model is that a large number of S&T professionals will emerge at the end of four years. Usually the science and arts graduates will be better equipped than their 3 year counterparts and could be on par with engineering counterparts for pursuing post graduate education and research.

A natural follow up of the four year model would be to allow them to pursue doctoral programmes in science and technology, without going through a Masters programme. There is no reason why a 4 year B.Tech in Computer Science can not pursue a PhD programme in Mathematics, or why a four year graduate in Chemistry or Physics can not pursue a PhD degree in Materials Science. It is worth recalling that it is the physicists turned biologists who laid the foundation of modern day molecular biology.

If this is approved, then a detailed structure will have to be worked out which is compatible with B.Tech Curriculum as outlined in Chapter II. The proposed changes can be accomplished through the introduction of a credit based, semester system in all engineering/science colleges/institutions with a common core of engineering/science in the first two years and a flexible professional stream in the last two years. Transfer of credits from one major to another major within the Institute and also between institutions should be enabled. The common core could consist of courses in mathematics, physics, chemistry, biology, humanities and social sciences, computing skills, communication skills, workshop practices and laboratory practices.

2. CO-LOCATING TEACHING AND RESEARCH INSTITUTIONS

A large number of educational institutions and R & D laboratories have come up in India over the last several decades. While efforts have been made to improve them individually and bring about interconnectivity between the two sets of institutions, the latter has not happened on a large scale. Instead, many research institutions have gone about getting deemed university status and many are still demanding the deemed university status.

Physical proximity between academic institutes and R&D institutions is likely to bring about better results. This has happened in the United States and many other countries. The classic examples are: Argonne National lab and the University of Chicago, Lawrence Livermore Laboratory and University of California Berkeley. Many scientists in the National labs take up adjunct faculty position in the University and many faculty members in the University take up positions in the research lab, particularly during summer. Such an arrangement has a large number of benefits:

- students get to take certain courses with well known practitioners in the field
- students get to undertake summer projects in areas of practical interest
- faculty are in touch with the latest in the field and have access to latest research equipment
- scientists interact with bright young minds and also with mature academic minds.

Practical implementation can be done in two ways. Firstly by forging ties between existing academic institutions and R&D labs and secondly by co-locating future R&D labs in/around existing /future academic institutions. Honorary/adjunct faculty positions can be offered to qualified scientists in neighboring R&D labs in the vicinity and part-time/summer appointments to faculty in R&D labs. R&D labs can offer summer project to students.

CHAPTER 5 - INDUSTRY-INSTITUTE INTERACTION

Over the last decade and a half, the falling of barriers to international trade and investment has led to a more integrated and interdependent framework of international business. Employers today, as a result, operate in an environment that demands new and constantly developing skills to retain global competitiveness.

While the government has been increasing investment in education and training as a proportion of national income, the effort has been inadequate to address the direct needs of the corporate sector. This calls for a collaborative effort by both Industry and Academia.

India's vast network of academic infrastructure churns out over 2 million graduates annually. However there are growing concerns about parts of the existing available talent pool being unsuitable for employment due to a skill gap. It's become imperative to enhance the Indian talent pool to maximize the industry's potential and enable the Industry to further catalyze the country's galloping economic growth rate.

One of the biggest human-power challenges being faced at the level of higher-end education is the paucity of PhDs and research scientists. Currently, post-graduate education is lagging behind undergraduate learning, with barely a handful of takers for the top-of-the-line PhD programs.

Many consortiums like NASSCOM, CII have over the last few years created a major workforce development platform and launched several initiatives, in partnership with the Government and academia that aim to bring positive changes to the Indian education system and its orientation towards building employable students. Following are some of the initiatives that can be taken up by Industry, Academia and Government together:

- Public Private Partnership model should be explored for setting up institutes of higher learning.
- Industries and Institutes should jointly contribute for research which will help the industries to come up with better and innovative products
- Industries and Institutes should start finishing schools as part of the continuing education activities which would help to train the students into Industry specific skill sets and thus make the students productive as soon as they join on the board.
- The industries may select final year engineering students from different engineering colleges and can offer 'Industry Specific Training' along with curricular learning in the colleges. The exposure to industrial working can be given through in-plant training during the vacations.
- Engineering students should go through their Industrial Training during their Engineering Curriculum so that they become aware of what Industry is looking for and they get molded to the environment early. Industry should design these training programmes and take students-training seriously.

- The current Apprenticeship Act should be amended to include option of training in multiple skills with provision of multiple entry and exit points.
- The Industries can start education training programmes for their employees in the industry by collaborating with suitable education institutes.
- There has to be constant dialogue among Educational Institutes, Industries and Government through seminars and workshops to keep educational institutes aware of the specific skill –sets requirements of various industries.

There is a need for effective intervention to understand requirements of the Industry, variable sector specific skills, training requirements that improve business performance, articulation of business expectations in education institutions and engagement of industry leaders with higher education institutions. More and more platforms should be developed that would bring together higher education institutions and Industries to evolve modalities for collaboration in order to meet India's medium and long – term skills and business needs for the 21st century.

CHAPTER 6 - DISTANCE EDUCATION

1. INTRODUCTION

In order to meet the rapidly expanding demand for education, India has no choice but to take advantage of developments in Information and Communication Technology (ICT) to offer education in the distance mode. The brick and mortar model is far too expensive. NKC had set up a Task Force on Open and Distance Education and have already submitted their recommendations to the Prime Minister. We merely mention here in passing that a national initiative has been started by MHRD in which IITs and IISc have been involved in creating curriculum based content in both video and web format for about 120 courses under the national programme on Technology Enhanced learning (NPTEL). Each course consists of about 40 lectures and is available free of cost to all engineering students / working professionals / teachers in India. The MHRD has also set up an ambitious programme:

A One Stop Education Portal for addressing all the education and learning related needs of students, scholars, teachers and lifelong learners called Sakshat is a landmark initiative of the Ministry of Human Resource Development (MHRD). The portal envisages providing one stop solution to educational requirements of learners ranging from K to 20 covering all fields of study including vocational education and learning for life skills. In Indian scenario where there is vast disparity of educational facilities available in various regions across the country, the Portal will help in bridging the gap by providing just in time quality educational resources and teachers 24×7 to learners irrespective of their social, economic and educational status. It is an endeavor through which MHRD hopes to synergize the efforts taken by the educational organizations/ agencies viz. UGC, AICTE, IGNOU, NCERT, KVS, NVS, CBSE, IITs, and IISc etc. to develop world class content. The main objectives of the portal are to:

- Provide barrier-free web based learning resources uniformly across the country
- Develop a repository of world class interactive multimedia learning content
- Nurture learners by providing web-based guidance and encouragement through synchronous and asynchronous modes of interaction
- Help in honing skills and knowledge through on-line mentoring and testing services
- Provide a platform for sharing of knowledge and experience among teachers and learners
- Regularly monitor the progress of scholars and other learners based on the performance in customized on-line tests
- Facilitate learners to make informed decision on choice of profession through on-line career counseling facility
- Nurture those who aspire for excellence

The Portal has the following five functional modules: Educational Resources, Scholarship, Testing, Superachiever, and Interact. Apart from the above modules the Portal has an inbuilt virtual class rich with multimedia learning resources.

This portal would be one of the important pillars of the National Mission on Education during the 11th Five Year Plan. The National Mission would address the requirement of providing broadband access to every Indian with zero charge for the bandwidth if this portal and its links are accessed. Development of low cost, affordable and appropriate access devices having very low power consumption would be yet another challenge for the Mission.

The website can be accessed at www.sakshat.ac.in; www.sakshat.edu.in; www.sakshat.ernet.in; http://sakshat.gov.in. The ‘Sakshat’ pilot Project is areas to ensure that no person is deprived of education for economic or social reasons Recommendations for future of distance learning in India

2. Recommendations for future of distance learning in India

- It has to be seen as a means to get the experts to every nook and corner of the country to improve education quality and not as a replacement strategy for faculty.
- Use the mechanism to drive the faculty development program.
- It has to be multimodal:

  Text and PPT files which are lessons accessible to Teachers and students alike asynchronously

  Video clippings to get the real life perspectives to students who can’t get internships

  Improve effective use of EDUSAT for reaching students in remote areas

  Create a portal based push mechanism to drive continuous learning;
- Build a bank of innovative projects that can be used by the colleges to drive self learning
- Assess and implement a digital infrastructure that will progressively reach out to the remote towns.
- Course content creation, new pedagogical innovation using the faculty of these colleges can foster continuous improvement.
- Provide opportunities for the faculty to obtain a research support and collaboration

CHAPTER 7 - REGULATION AND GOVERNANCE

1. REGULATION

All (university) education in India is on the concurrent list. This means the responsibility for making education available to the public is divided between Central Government and state government. Engineering Education is administered by the Central Government through the Ministry of HRD through the autonomous All India Council for Technical Education (AICTE). Over the last decade, the number of seats in private Engineering colleges has increased exponentially and is estimated at 80% of the total enrolment. It appears that if faults in the UG education system are corrected and attended to properly then the health of the entire engineering education system can be improved.

AICTE was set-up in November 1945 as a national level Apex Advisory Body to conduct survey on the facilities on technical education and to promote development in the country in a coordinated and integrated manner [8]. Later, the National Policy of Education (1986) empowered AICTE with statutory powers since 1988. The planning, formulation and maintenance of norms and standards, quality assurance through accreditation, funding in priority areas, monitoring and evaluation, maintaining parity of certification and awards and ensuring coordinated and integrated development and management of technical education in the country came under the purview of AICTE.

The State higher technical education ministry implements their plans through the Universities under the overall supervision of AICTE. AICTE though a central government body which is 'autonomous', provides the guidelines for standards in professional programs and is also charged with licensing and accrediting the colleges as well as introducing new programs in education.

It is important to release all colleges from the current tyranny of approval cycles. Instead, mechanism of laying down minimum standards for the infrastructure, processes etc may be articulated and made known nationally. These could be periodically updated as required through a consultative process involving institutions and the users. Colleges should have the freedom to work their own way and do self-certification. They should be mandated to obtain annual "Chartered Educationist Certificate". Chartered Educationist should perform the role of auditing and special accreditation. It is crucial to avoid a single accrediting agency as it will lead to lowering of the standards through corruption.

Regulatory Authority – An apex independent regulatory authority should be established that can achieve the objectives of regulation without political interference. The Committee supports setting up Independent Regulatory Authority on Higher Education as recommended by NKC as part of Higher Education. An autonomous Standing Committee for Engineering Education should be established whose main role would be to exercise due diligence at the point it approves a license to grant degrees/diplomas.

Objectives of Regulation:

- To provide an overarching architecture for engineering education and bring it under a single framework for the country while attending to the social responsibility of the government; through affirmative action policies.
- To support meritocracy as a central theme and help the underprivileged through alternative financing and tutorial structures.
- To be the ombudsman for change to make the nation competitive.
- To progressively push for deregulation while guarding against monopoly practices.
- To bring about global standards and encourage the pursuit of Post Graduate programs to foment innovation for economic growth.

Composition:

The members of such an authority have to be chosen through an international committee consisting the best educationists, education administrators, management specialists drawn from Industry, change management specialists.

- The team has to have representation from a mix of experience and youth both in industry and educational institutions.
- It has to have representation from both genders.
- It should only regulate the standards and not act as a licensing body.

Accreditation - Currently the National Board of Accreditation (NBA) set up as an independent body by the AICTE is responsible for accreditation. It is equally important that the Accrediting body should be insulated from external influences. The Standing Committee on Engineering Education shall determine the criteria and the processes of accreditation in consultation with experts from academia and industry. It will then license multiple agencies which could undertake accreditation.

It is critical that Regulatory and Accrediting bodies be free of corruption and insulated from political influences. As of now neither AICTE nor the NBA satisfy these criteria.

Grading of Institutions - It is essential to introduce ranking of institutions based on overall performance as well as sector specific rankings. This need not be based only on technical but also on inclusivity, gender equality, international practice, non academic parameters like in USA. The Standing Committee will stipulate grading norms and nominate independent rating agencies to assess and categorize Engineering institutions

2. GOVERNANCE

One of the most important issues is that of autonomy. Education can flourish only when the teachers in the classrooms are empowered. A teacher in an affiliated college today has no control on the education that he is expected to impart. Someone else sets his syllabus and someone else examines his students. How does he show what he is capable of and how does he implement any of his own ideas? Enquiry-based education is not possible under these circumstances.

The affiliating setup does not offer incentives to colleges for better performance. Students from all colleges, whatever the quality, get the same degree.

- The system of affiliating universities should be abolished as soon as possible. Every college be given full autonomy teaching their own curricula and giving there own degrees.
- Autonomy for the college includes autonomy not only for the management, but all the way down to individual teacher so as to encourage experimentation.

3. TRANSPARENCY

It should be compulsory for all colleges to give all information related to buildings, labs, faculty information, input students, output performance of students, placements, Chartered Educationist report etc. on the website – so that parents, students, consultants, media etc can see the trends. That will lead to better public accountability than the present approval or affiliating Universities process. Such information will also determine the fees that are chargeable through market forces. Colleges may cluster themselves, if they desire for common entry processes, academic matters etc. Some of them can seek the tutelage of IITs.

In order to ensure transparency on the part of management a University Institute Charter (UIC) should be set up.

The UIC should develop mechanisms by which the commitment of the Institute to the following processes are coordinated: 1. provide transparency in admission and registration in different programmes of study, 2. provide an effective teaching and learning environment, guidance and supervision through a variety of study methods, 3. tutorial support, 4. student academic representation – appropriate committees, 5. provide a high standard of academic services to all students, 6. provide quality service to students outside the curriculum – extracurricular activities, 7 ensure health, safety and security as far as possible and 8. provide institutional mechanism for addressing major concerns of students and parents.

An institutionalized mechanism for addressing the major concerns of students and their parents is also essential. A Students' Charter (SC) should also be introduced. The SC is a document which aims to set out, as clearly as possible, what standards of service can be expected by students and what the university / institute / college can expect of students in return. Such charters are common features in colleges and universities in the west. It is an expression of the close working relationship between administration, faculty and students and their shared commitment to maintaining and enhancing excellence in the educational experience of its students.

The best practices (semester system of instruction, continuous evaluation of student's comprehension rather than the traditional annual examinations, greater involvement and freedom to instructors in curriculum making and academic evaluation, relative grading, student evaluation of instructor's pedagogy) of higher education should be made available for institutions to adopt them if they feel they are appropriate.

RECOMMENDATIONS

Following is the set of recommendations that Working Group has come up with after a series of serious deliberation.

1. Access and Inclusiveness

a. Government should set up new engineering institutions in the under provided regions

b. Government should consider setting aside funds for helping poor students get through the entrance tests and later pay the fees in institutions of the students' choice. The government funds should go to the poor and needy in the form of grants and soft loans for coaching and for fees after admission rather than negotiating with the institutions for lower fees.

2. Faculty

Increasing the number of faculty

a. Relaxing the criterion of holding a PhD degree for undergraduate teaching – Though faculty with PhD degrees are desirable, given the current state of affairs, this criterion must be relaxed to faculty holding Master's degree in institutions that only offer undergraduate education. In order to ensure the requisite breadth of knowledge of subjects in such faculty, an alternative approach to the Master's degree is recommended. Exposing students to more course-work in place of the one-year project. In the long run, the faculty currently holding B.Tech degree should be encouraged to acquire a Master's degree as early as possible.

b. Increasing the PhD manpower – Measures should be taken to increase the PhD manpower. Good quality graduate students must be motivated for doing PhD. Attractive incentives through opportunity for international exposure like attending international conferences or exchange programs must be provided. A similar scheme which enables a faculty member to spend two months per year working at the site of his international collaborator should also be put in place. Vibrant PhD programmes to attract good students who currently go abroad for doing their PhDs should also be rolled out. Undergraduate in sciences or engineering should be allowed to pursue a PhD program (with scholarship) directly in either sciences or engineering with considerable flexibility irrespective of their background.

c. Adjunct/Additional Faculty – Professionals from industry and research laboratories should be invited to participate in the teaching process. Institutions should be encouraged to create adjunct positions for them. The upcoming research institutions should be co-located with academic institutions and vice-versa to facilitate this participation. Existing institutions with active research programmes should be supported by the government to set up high-tech industrial research parks in the vicinity of their campuses. Internationally competitive talent must be attracted by providing incentives such as better working environments and globally competitive opportunities.

d. Tap potential faculty at early stage – Those who have potential and inclination towards teaching should be identified at their undergraduate level and motivated to take teaching as a career. Opportunities must exist for these teachers to experiment with innovative content and pedagogy along with the opportunity to pursue for further studies.

e. Other incentives – In the absence of research opportunities in undergraduate degree granting institutions, a teacher needs incentives which enable him/her to grow professionally. This could be achieved through provisions like secondment to industry during vacation time enabling a faculty member to improve his or her practical skills.

Ensuring Quality

f. Continuing Education in Distance Mode – Opportunities should be available for faculty to enhance their knowledge and teaching skills through coursework of a rigorous nature using open distance mode. Institutes of excellence like IITs should be encouraged to make available such courses in all modes.

g. The short-term training programmes including the induction programmes conducted by Academic Staff Colleges set up by UGC should be modified away from the present content-independent model. There is a need to set up training programmes that teach teachers on what and how to include in courses.

h. A one-day regional workshop on teaching/learning processes by carefully identified good teachers and by educational technology experts should be arranged atleast once a year as part of the academic calendar. The workshop should focus on one or two aspects of teaching as an aid to improving the quality of education.

i. Teacher induction training dealing with the basics should be insisted upon for anyone who wants to be an engineering teacher. This could be a two weeks contact course conducted by senior mentoring faculty at the national level. It is advisable for premier institutions to put up such teacher training courses for those who cannot attend such in-person programmes. Subsequent periodic refresher courses should be organized.

3. <u>Teaching Learning Processes</u>

a. In the entire teaching learning process, it is important that teachers should be provided complete autonomy while ensuring accountability by using proper checks and balances.

b. In view of changing industry needs, universities should work out a healthy balance between the wholeness of knowledge and specialized courses. Teacher should concentrate on fundamentals, the framework for incorporating empirical knowledge and on imparting problem solving skills. Academic institutions must consider an inclusive approach to integrate skills in the teaching learning process for the holistic development of the individual. Some of these skills include i. Problem Solving and Logical Reasoning (Analytical Ability), ii. Process Orientation (Attention to Detail) iii. Learning Ability iv. English Communication

(Written and Verbal i.e. non-voice) and v. Programming fundamentals (the generic domain). As far as possible, these skill sets should be integrated as part of all subjects and not taught as separate courses. Industry participation to discuss real life case studies should be encouraged.

c. There is a need for introduction of a credit based, semester system in all engineering/science colleges/institutions with a common core of engineering/science in the first two years and a flexible professional stream in the last two years. Transfer of credits from one major to another major within the Institute and also between institutions should be enabled. The common core could consist of courses in mathematics, physics, chemistry, biology, humanities and social sciences, computing skills, communication skills, workshop practices and laboratory practices

d. Curriculum - The current curriculum should be modified to provide flexibility, interdisciplinarity and choice of electives. A self study course to encourage independent study, project work in as many courses as possible to engage diverse groups of students together and one course on current topics of social or industrial or national relevance. A flavour of engineering should be given in the first semester itself. At least one of the Humanities courses should concentrate on developing oral and written communication skills.

   Laboratory courses should be revamped to include familiarization with standard equipment and measurement techniques and students should be helped to develop a health attitude to experimental work.

   Although voluntary in nature, students at all levels must be encouraged/ motivated/ persuaded to participate actively in co-curricular activities.

e. Pedagogy - Where appropriate teachers should be encouraged to use audio-visual aids including computers in the classrooms to improve communication between them and the students. At least a few modern class-rooms should be set-up in each department. Videotaped feed-back should be provided to help faculty improve their teaching methods.

f. Evaluation of Students - Faculty should have the freedom to design their own evaluation systems and experiment with them. However, the evaluation scheme must be clearly spelt out early in the course. It is desirable that students are evaluated continuously for their learning.

g. Feedback on Teaching - Teacher evaluation and course evaluation must be conducted scientifically using different feedback forms for theory and laboratory. These processes should be computerized in order to provide early and comprehensive feedback to the teachers.

h. Teacher-student and student-student relationships – Teacher student relationships outside the classrooms should be encouraged by providing different structured avenues in which both participate informally.

4. <u>Integerating Sciences and Engineering Education</u>

a. In order to reduce the perceived gap between science and engineering, it is desirable to start four year undergraduate programs in science along the lines of engineering programmes. These can take off initially in institutes of excellence where facilities for science programs already exist.

5. <u>Industry Institute Interaction</u>

a. In order to meet the increasing demand, more institutes of excellence need to be established. Public private partnership could be explored for the same purpose. However, all polytechnics should be operated in PPP mode.

b. Frequent dialogues among Educational Institutes, Industries and Government through seminars and workshops are necessary to keep all informed about the latest trends and issues.

c. Academia and industry should engage in joint research in order to improve innovation and competitiveness in the global economy of today.

d. In order to solve the issue of employability of graduate, an exposure to industry in form of Industrial Training should be provided to students during their tenure. Finishing schools should be started as a joint venture to train the students in Industry specific skill sets upon graduation.

e. The industries may select final year engineering students from different engineering colleges and can offer 'Industry Specific Training' during the vacation to supplement the curricular learning in the colleges.

f. The current Apprenticeship Act should be amended to include option of training in multiple skills with provision of multiple entry and exit.

g. The Industries can encourage continuing education programmes for their employees by collaborating with suitable education institutes

6. <u>Distance Education (DE)</u>

a. Universities must take full advantage of developments in ICT since the brick-and-mortar model is likely to be too expensive – to meet the explore increase in demand for higher education.

b. DE should be used to drive the faculty development program to a great extent

c. Different modes of learning (both offline and online) should be explored in order to work with the existing limitation of suitable infrastructure. In this regard, Create a portal based push mechanism to drive continuous learning and build a bank of innovative projects that can be used by the colleges to drive self learning. Feedback mechanism should be established for continuous improvement of pedagogy.

d. Work towards quality access by enabling world class infrastructure even in the remote areas of the country.

7. <u>Regulation</u>

a. An apex independent regulatory authority should be established that can achieve the objectives of regulation without political interference. An autonomous Standing Committee for Engineering Education should be established under proposed Independent Regulatory Authority of Higher Education. Its main role would be to exercise due diligence at the point it approves a license to grant degrees/diplomas. The members of such an authority have to be chosen through an international committee consisting the best educationists, education administrators, management specialists drawn from Industry and change management specialists

b. Establish a system of "Chartered Educationist Certificate" under which Chartered Educationist will perform the role of auditing and institutions will be mandated to undertake the entire auditing process. In order to ensure success, multiple independent agencies should be established.

c. Accreditation of Institutions –The Standing Committee on Engineering Education shall determine the criteria and the processes of accreditation in consultation with experts from academia and industry. It will then license multiple agencies which could undertake accreditation.

d. Ranking of Institutions **-** It is essential to introduce ranking of institutions based on overall performance as well as sector specific performance based not only on technical but also on inclusivity, gender equality, international practice, non academic parameters like in USA. The Standing Committee will stipulate grading norms and nominate independent rating agencies to assess and categorize Engineering institutions

8. Governance

a. Autonomy to institutions – The system of affiliation should be done away with as soon as possible. Every college should be given full autonomy not only for the management, but all the way down to individual teacher so as to encourage experimentation

b. Transparency - It should be made compulsory for all colleges to give all information about their buildings, labs, faculty, intake of students, output performance of students, placements, Chartered Educationist report etc. on the website – so that parents, students, consultants, media etc can see the trends and make informed decisions. In order to ensure transparency on the part of management a University-Institute Charter (UIC) should be set up to provide: transparency in admission and registration in different programmes of study, an effective teaching and learning environment, guidance and supervision through a variety of study methods, tutorial support, student academic representation, extracurricular activities, provide institutional mechanism for addressing major concerns of students and parents and ensure health, safety and security as far as possible. At the same time, a Student Charter should also be introduced which clearly spells out standards of service expected by and from students.

c. Institutes should consider having two cells - Counselling Cell and Training and Placement Cell. The former is more of general nature where students especially the ones in first year get help to adjust in a new environment. The latter is to help graduating students to prepare themselves for the placement as well to handle the stress of a failure.

9. Others

a. The Government should help the elite institutions maintain their excellence. Policy framework and procedural simplicity should be such as to enable more and more institutions to become elite. At the same time, in such elite institutions, the emphasis should be on global level of excellence in teaching, research, and consultancy. Competition and collaboration between these institutions will lead to many creative and innovative educational methodologies in India and set trends for the other engineering colleges to follow.

b. Additionally, the elite institutions should consider some additional responsibilities such as (i) adopting a few engineering institutions of their choice and help them raise their standards as part of their corporate responsibility, (ii) creating educational resources for use of students in other engineering colleges and make them available in the public domain and (iii) conduct distance education courses especially at the post-graduate level for students as well as working professionals.

Glossary

AICTE All India Council for Technical Education
B.E. Bachelor of Engineering
B.Tech Bachelor of Technology
BPO Business Process Outsourcing
CII Confederation of Indian Industries
CSIR Council of Scientific and Industrial Research
ESO Engineering Services Outsourcing
FICCI Federation of Indian Chambers of Commerce and Industry
ICT Information and Communication Technology
IGNOU Indira Gandhi National Open University
IISc Indian Institute of Science
IISER Indian Institutes of Science Education and Research
IIT Indian Institute of Technology
ITO Information Technology Outsourcing
M.E. Master of Engineering
M.Tech Master of Technology
MIT Massachusetts Institute of Technology
MHRD Ministry of Human Resource and Development
NAC-Tech NASSCOM Assessment of Competence –Technology
NASSCOM National Association of Software and Service Companies
NBA National Board of Accreditation
NCC National Cadet Corps
NCERT National Council of Education Research and Training
NIT National Institute of Technology
NITTTR National Institute of Technical Teacher's Training & Research
NSO National Sports Organization
NSS National Service Scheme
NPTEL National Programme on Technology Enhanced Learning
PG Post Graduate
PPP Public Private Partnership
UG Under Graduate
UGC University Grant Commission
UIC University Institute Charter

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ANNEXURE -1

This section contains statistics on Engineering Education. This data has been borrowed from *'Rangan Banerjee, Vinayak P. Muley, Engineering Education in India, Observer Research Foundation, Sep 2007'*

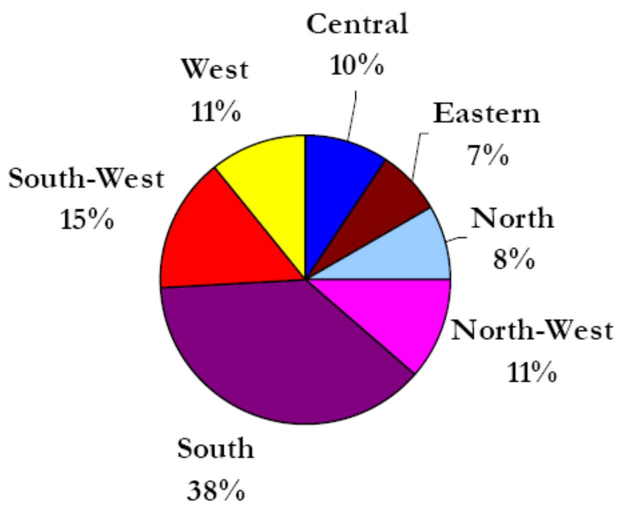

Figure 1: Region-wise Distribution of Sanctioned Intake

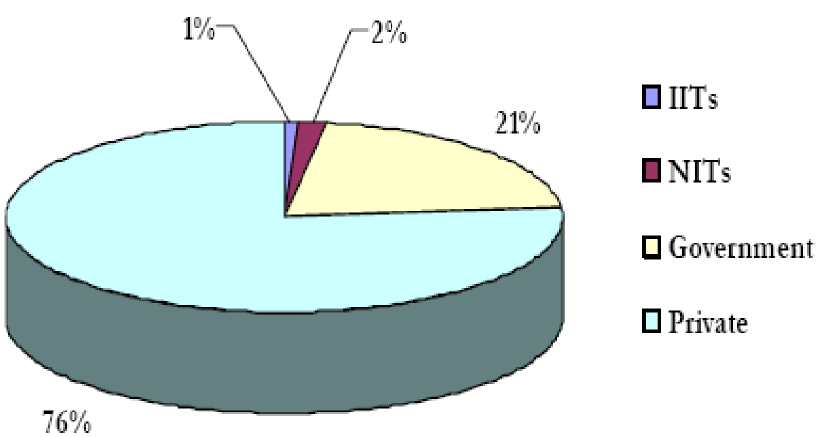

Figure 2: Share of Engineering Colleges based on intake (2006)

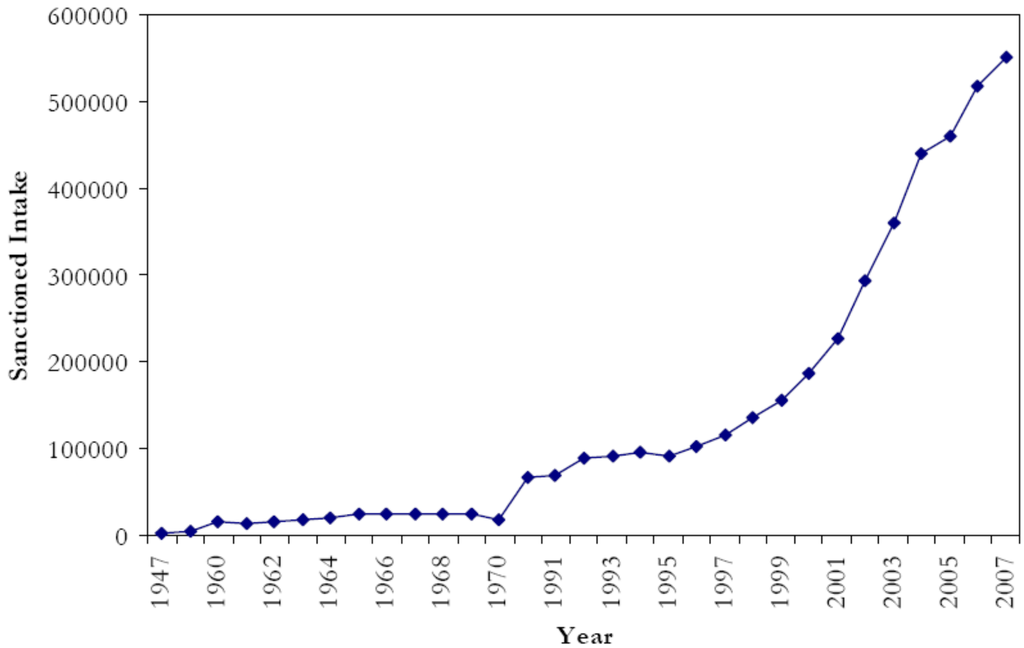

Figure 3: Growth of Sanctioned Intake of Graduates from 1947-2007

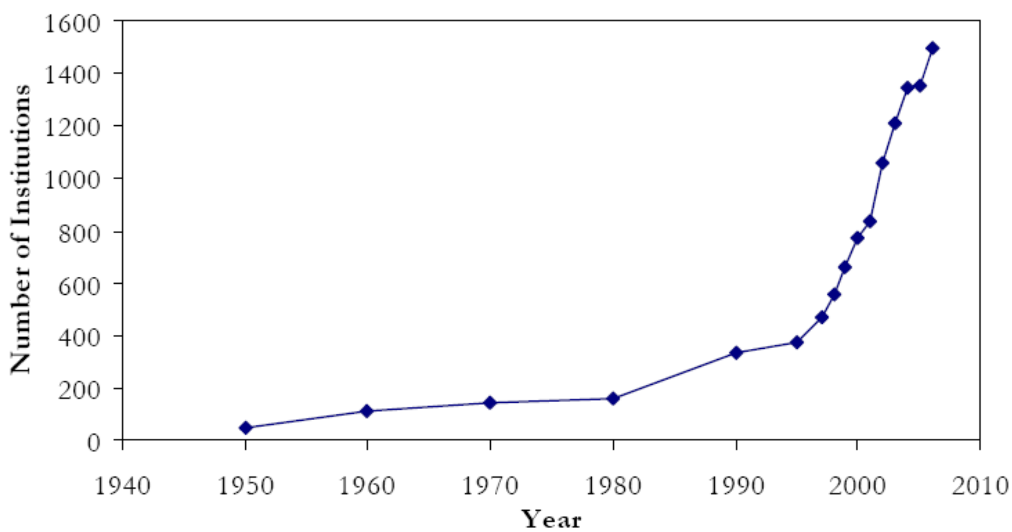

Figure 4: Growth of Degree Institutions 1950-2006

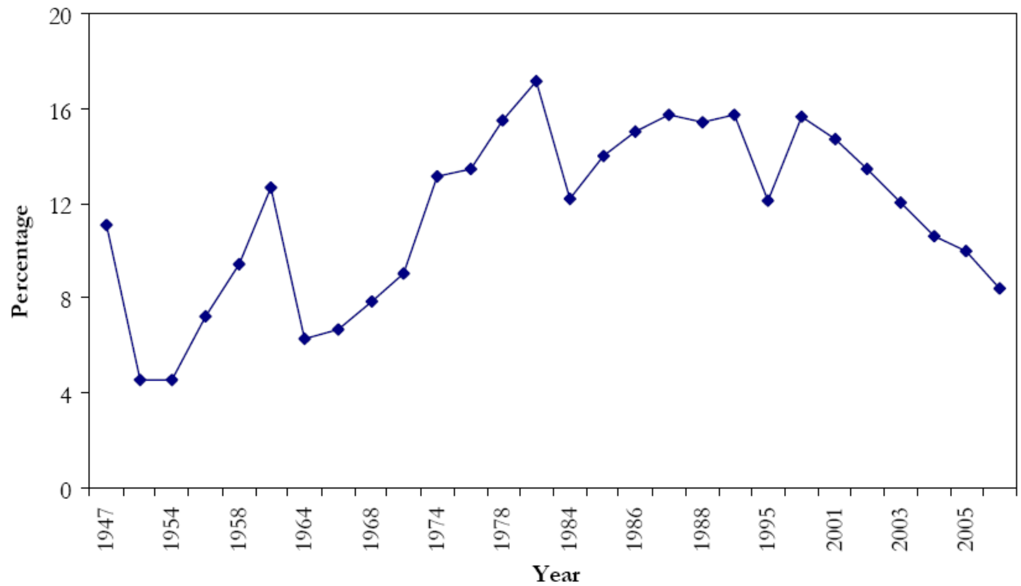

Figure 5: Percentage of Masters output to Graduate Engineers output

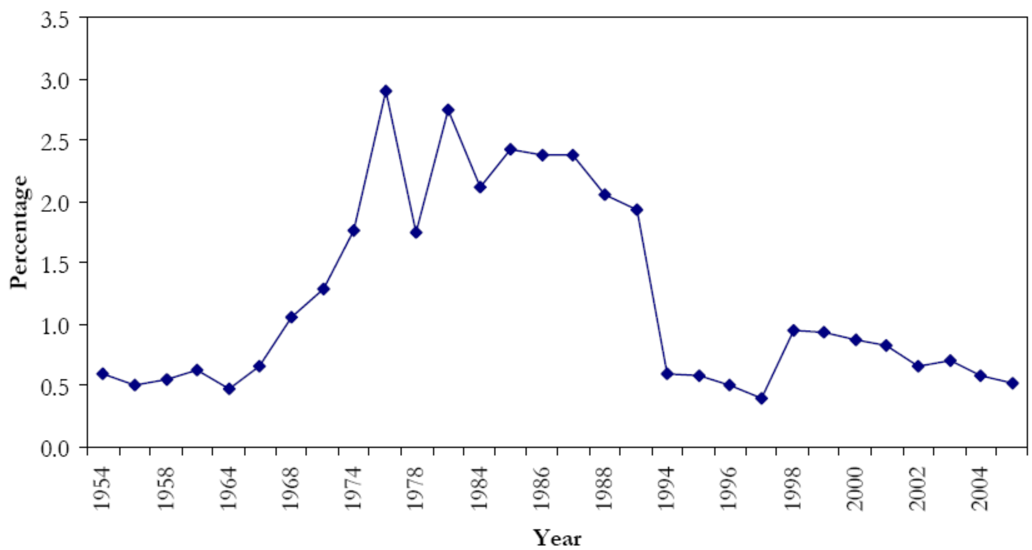

Figure 6: Percentage of PhD output to Graduate Engineers output

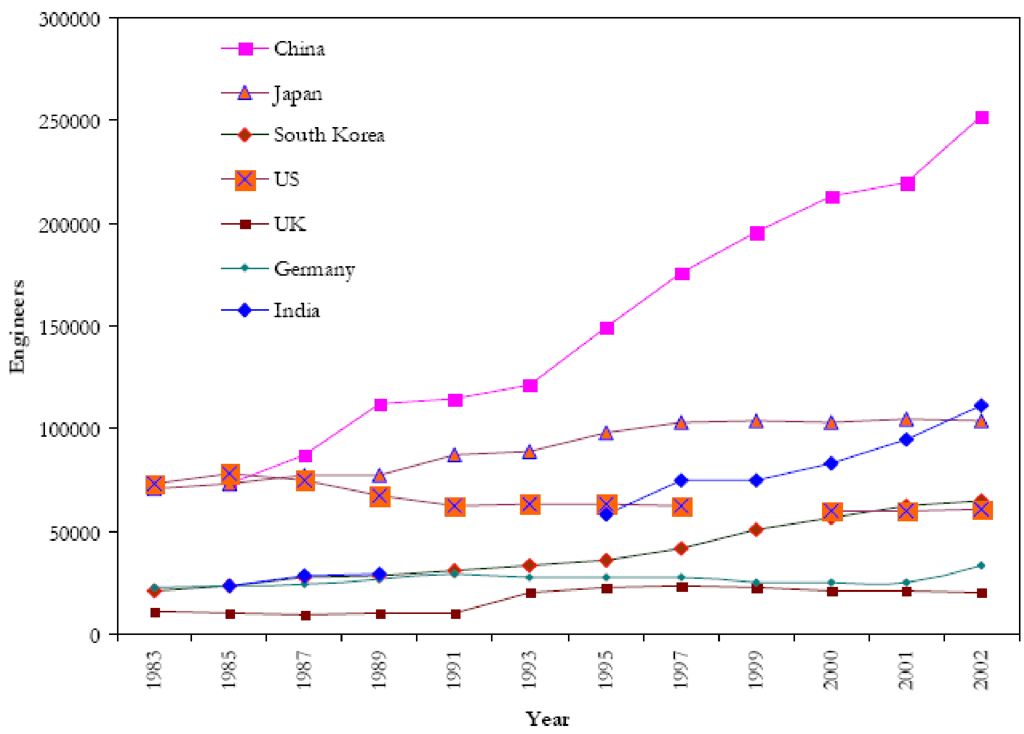

Figure 7: Engineering Graduates in Different Countries

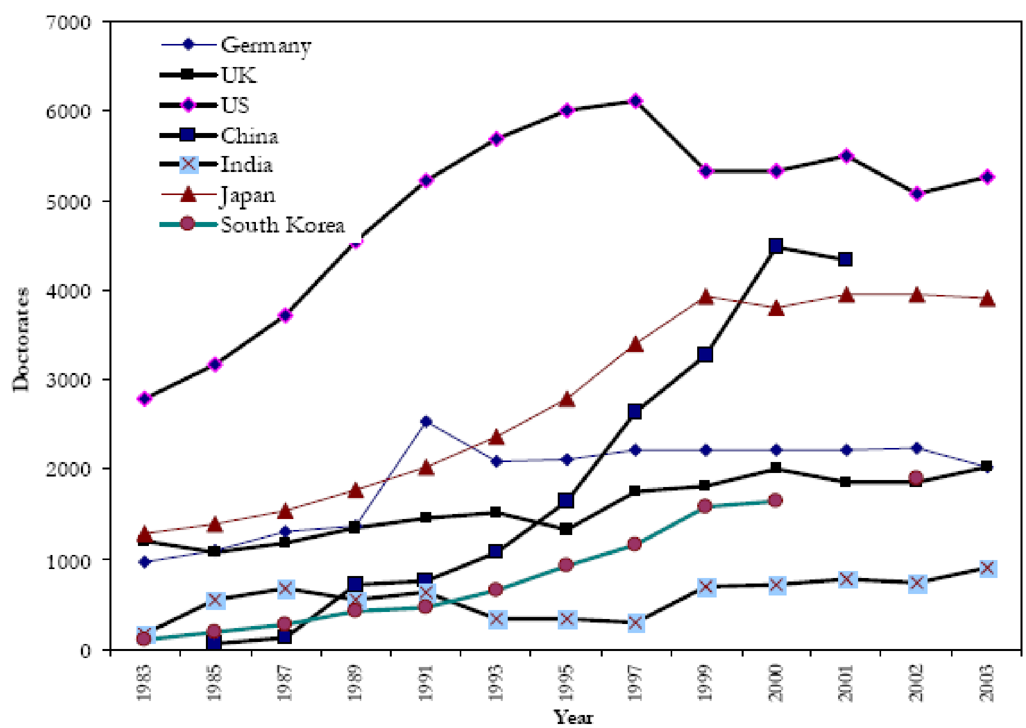

Figure 8: Engineering Doctorates for Different Countries

Region	State	Number of Institutions	Intake	Population Million	Intake per million Population
Central	Madhya Pradesh	84	30060	60.3	498
	Chhattisgarh	15	5130	20.8	246
	Gujarat	43	14086	50.7	278
Eastern	Mizoram	0	0	0.9	0
	Sikkim	1	465	0.5	860
	Orissa	48	15033	36.8	408
	West Bengal	54	15671	80.2	195
	Tripura	1	250	3.2	78
	Meghalaya	1	240	2.3	104
	Arunachal Pradesh	1	210	1.1	191
	Andaman & Nicobar	0	0	0.4	0
	Assam	4	670	26.7	25
	Manipur	1	115	2.2	53
	Nagaland	0	0	1.2	0
	Jharkhand	9	3198	26.1	119
North	Bihar	6	1690	82.1	20
	Uttar Pradesh	110	40418	166.2	243
	Uttranchal	13	3905	8.5	460
North-West	Chandigarh	5	788	0.9	875
	Haryana	45	16325	21.1	772
	Jammu & Kashmir	6	1401	10.1	138
	New Delhi	16	6359	13.9	459
	Punjab	47	16961	24.4	696
	Rajasthan	47	16051	56.5	284
	Himachal Pradesh	6	1282	6.0	211
South	Andhra Pradesh	280	107575	76.2	1412
	Pondicherry	5	2295	0.1	2355
	Tamil Nadu	268	105318	62.4	1688
South-West	Karnataka	128	56542	52.9	1070
	Kerala	93	29165	31.8	916
West	Maharashtra	171	58989	96.9	609
	Goa	3	794	1.3	589
	Daman & D. Dadar	0	0	0.4	0
	Total	**1511**	**550986**	**1025.1**	**536**

Table 5: State-wise Distribution of students' intake (2006)

Institute/University	Student Output				Faculty	B/F	S/F ratio	Ph.D./ Bachelors	Research Fund (million)	Papers	Research Fund in Rs (PPP)	
	Bachelors	Masters	Ph.D.	TED							Million	Lakhs/ faculty
Massachusetts Institute of Technology USA	578	745	135	1458	372	1.6	8	0.23	US $234.5	3129	1876	50.4
Univ. of Illinois, Urbana-Champaign USA	1237	554	156	1947	441	2.8	15	0.13	US $200.1	2251	1600.8	36.3
Purdue University USA	1238	461	144	1843	309	4.0	19	0.12	US $112.3	2648	898.4	29.1
Georgia Institute of Technology USA	1391	751	162	2304	419	3.3	20	0.12	US $203.7	2811	1629.6	38.9
California Institute of Technology USA	247	120	277	644	398	0.6	6	1.12	US $80.4	2885	643.2	16.2
Imperial College UK	695	600	160	1455	291	2.4	15	0.23	UK £ 63.4	2674	768.408	26.4
Tsinghua University China	2100	1400	500	4000	1200	1.8	12	0.24	NA	6590	NA	NA
Tokyo Institute of Technology Japan	980	1633	382	2995	906	1.1	10	0.39	NA	3993	NA	NA
Nanyang Technological University Singapore	2635	1400	500	4535	1020	2.6	27	0.19	NA	2564	NA	NA
National University of Singapore	1402	570	119	2091	288	4.9	20	0.08	S$82.5	1933	532.1	1.8
Pohang University of Science and Technology Korea	306	329	134	769	305	1.3	11	0.44	NA	1259	NA	NA
Korea Advanced Institute of Science and Technology	755	731	390	1876	418	1.8	18	0.52	NA	939	NA	NA
IISc Bangalore	0	337	165	502	432	0.0	3		Rs 1024	1274	1024	23.7
IIT Bombay	422	581	56	1059	401	1.1	12	0.13	Rs 520	568	520	13.0
IIT Total	2316	3449	262	6027	2400	1.0	12	0.11	NA	3942	NA	NA
NIT Total	7000	1550	120	8670	2215	3.2	15	0.02	NA	678	NA	NA
Manipal (MIT, India)	751	81		832	280	2.7	13		NA	33	NA	NA

Table 6: Comparison of Indian Engineering Institutions with select International Universities

ANNEXURE – II

List of Working Group Members

1. Professor M. S. Ananth (Chairman)
   Director, Indian Institute of Technology Madras
2. Professor Anil Marathe
   Indian Institute of Technology Bombay
3. Professor Ashok Thakur
   Vice Chancellor, West Bengal Technical University
4. Professor Gokhale
   Director, National Institute of Technology Nagpur
5. Professor S. N. Maheshwari
   Indian Institute of Technology Delhi
6. Professor N Satyamurthy
   Indian Institute of Technology Kanpur
7. Professor Vijay Gupta
   Director, Punjab Engineering College, Chandigarh.
8. Dr. Ravindra
   Vice President, Education, Infosys, Bangalore
9. Dr. Y.S. Rajan,
   Principal Adviser, Confederation of Indian Industries
10. Dr. Sandhya Chintala
    Director, Education Initiatives, NASSCOM
    on behalf of Dr. Kiran Karnik, Chairman, NASSCOM
11. Mr. Baba Kalyani
    Chairman and MD, Bharat Forge, Mumbai

Terms of Reference for the Working Group

1. Identify constraints, problems and challenges relating to curriculum, teaching, infrastructure, administration and access.

2. Recommend changes and reforms to address the problems and challenges relating to curriculum, teaching, infrastructure, administration and access.

3. Recommend changes in the pedagogy of teaching and suggest ways to use technology in order to improve the same. Suggest ways of incorporating emerging fields of engineering education in teaching and curricula.

4. Recommend methods of attracting and retaining talented faculty members; revisit the minimum qualifications for appointing teachers and principals. Suggest ways and criteria in order to have continuous training of faculty during the course of their term.

5. Identify issues related to current evaluation system. Suggest effective methods of evaluating students.

6. Suggest ways to increase industry-academia interaction, role and involvement of industries in undergraduate and postgraduate training and research.

7. Revisit the concept of Distance Education Program and identify challenges relating to the same.

8. Identify problems implicit in regulatory structures that constrain the quality and spread of engineering education and suggest reforms for the same.

9. Examine issues of autonomy and accountability of institutions; suggest changes in the governance management and funding process.

10. Examine any other issues that may be relevant in this context such as factors that define the willingness of students to persist in engineering related activities