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Design of an Engineering Curriculum

A Note

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Introduction

Education is a key element of infrastructure for the growth of a society. The educational infrastructure has several layers such as primary education, secondary education, technical education and higher education. The economic strength of a society depends on the standard of educational infrastructure, in general, and the quality of technical education, in particular. Any society must ensure a free, creative and high-caliber university environment so as to produce successful captains of that society. The higher education system consists of three major components - (i) liberal arts and social sciences, (ii) technical and professional fields and (iii) basic and natural sciences. In India, the growth in the field of technical and professional education over the past 50 years is phenomenal. This growth has fuelled the developments in the fields of engineering and information technology. However, this development needs to be reviewed in view of global competition as well as an increase in demand for trained quality manpower from industry for design and manufacturing.

The economy of a country has three segments - agriculture, manufacturing and services. For a small country like Singapore, the economy can survive and even prosper with only one or two segments. However, for a large country like India, the economy has to progress on all three segments. In order to achieve an overall rate of growth around 8 to 10 percent, it is imperative that all three segments have to progress simultaneously. The services sector, including IT, requires well trained, technical manpower. The manufacturing sector requires significant investments in infrastructure as well as an excellent cadre of design and manufacturing engineers. The agriculture sector also needs personnel who are familiar with modern techniques. In short, a well-trained technical manpower is a key element for the overall progress of the economy.

India can be proud to have the largest technical education system in the world. Today, the country produces about 450,000 graduates in engineering per year. This can be compared to China producing 270,000 graduates per year and U.S.A. producing about 70,000 graduates per year. In India, the intake of students in technical education is about 500,000 per year. The number of technical institutions in India is about 1700. The country has a three tier structure of higher technical education. The IITs and IISc form the first tier. The NITs, IIITs as well as national institutions such as Institute of Technology at BHU, Zakir Hussain College of Engineering at AMU, Jadavpur University, JNTU constitute the second tier. The Government Engineering Colleges as well as Private Engineering Colleges form the third tier. The growth of technical education in India over the past twenty-five years is phenomenal. This growth has also brought along some serious concern of quality as well as efficiency. Many experts have expressed serious concern about the state of technical education in India.

The country could boast of a set of fine institutions for technical education in the pre-Independence era. Roorkee University, Guindy College, VJTI, COEP are some examples. Even eminent world-class engineers such as Sir M. Visvesaryya emerged during that period. However, the state of affairs has

declined in the recent past. In spite of the fact that establishments in space, nuclear and defense areas have come up in the past fifty years, the quality of engineers and scientists has deteriorated considerably. The country has established a large manufacturing base in automotive, aerospace, chemical, metallurgical and electrical goods. However, the country has not developed a strong base of design capabilities. Furthermore, many young engineering graduates are lured away by software industry. Therefore, there is a paucity of quality manpower in the manufacturing sector. It is opined that China shall be the hub of manufacturing and India shall be the hub of IT. However, such a situation is not tenable for sustainable overall growth of the country. It is necessary to increase the number of quality manpower in design and manufacturing during the coming years.

The IIT system has established a strong brand for undergraduate education in engineering. One of the key elements of this success is the Joint Entrance Examination. This entrance test and subsequent selection process is impeccable. The process ensures that bright students are selected without any compromise. They are then put in a liberal, free academic environment and challenged intellectually to learn the most demanding concepts of science and engineering. This kind of education imbibes a sense of intellectual confidence in IIT graduates. The education is so foundational that even though the graduates of IITs go in for other professions such as management or business, they continue to shine as the top, star performers. The sense of “can do it” confidence is instilled in the IIT curriculum and IIT campus environment. The successful alumni of IIT system is a galaxy of star studded canvas of Indian achievers spread all over the world.

The Indian society is hungry for more IIT-like education for its star value. In year 2006, about 300,000 students appeared for the Joint Entrance Examination (JEE) and only 5,000 were selected. This is a very steep filter and is frustrating to many in Indian society. There are as many as another 5,000 students who are equally brilliant but could not make it into the first 5,000. In fact, the next 15,000 are as good as the first 5,000. It is really necessary to provide IIT education to

these deserving candidates as well. In other words, the pyramid of selection tapers very sharply at the top and should be broadened. The only way it can be achieved is by enlarging the intake of existing IITs or setting up satellite campuses of existing IITs or setting up new IITs. Ideally, it is desirable to have an intake of 20,000 students for undergraduate programs at IITs. At present, it is 5,000. In short, there is an urgent need to correct this situation. It is strongly felt that setting up of new IITs is a desirable strategy to expand the base of IIT education.

The IIT system started in 50's and early 60's with five IITs - Kharagpur, Chennai, Mumbai, Kanpur and New Delhi. Later on, IIT Guwahati was established in early 90's. The University of Roorkee was converted to IIT in late 90's. This entire system is admitting about 5,000 undergraduate students from a group of 300,000. The expansion of capacity of the first five campuses was carried out in 90's. The strength was almost doubled. Now, the system is envisaged to expand its capacity by 54%. In short, the intake will go up to 8,000. Even then, it is found that several talented young students will be deprived of an opportunity to get quality education. If three to five institutes are started then each institute could admit about 1,000 so that it will be possible to add 3,000 to 5,000 students. In other words, the total system at the end of eleventh five year plan period could admit about 12,000 students. There are about seven institutions identified by Government of India for up-gradation to the level of IITs. These institutions together could ramp up their intake to a level of 8,000 at the end of eleventh plan. In short, the total intake at the end of eleventh plan period will be about 20,000 approximately.

The Scientific Advisory Council to the Prime Minister (SAC - PM) has strongly recommended establishing three premier technical institutions such as IITs for engineering education and research. For a country like India, it is necessary to have more than three such institutions. However, taking into account the financial constraints and taking into account the enormity of the task,

it is suggested that based on the experience of these three institutions, the Government of India should consider establishing additional institutions in future.

Need & Justification for a new Curriculum

India needs to develop a strong engineering base of economy. The present boom in the sector of services will be short-lived if neighboring countries catch up on offering cheap labor rates as well. The manufacturing base of Indian economy needs to be strengthened. Such a strengthening needs a new ethos of innovation and manufacturing entrepreneurship. In order to nurture these values, it is necessary to set up new academic institutions which will promote a new brand of engineering culture. It is felt that a new generation of Indian Institutes of Technology should develop the post-graduate education for innovation and manufacturing entrepreneurship.

Technology development is a key driver of new economy. Most of the technology development work is carried out by the institutes of technology in any country. It is carried out as a tripartite efforts on behalf of industry, Government and academia. The Samtel Centre established at IIT Kanpur is an excellent example of how globally competitive technology can be developed in India using such a collaborative effort. Academia and industry will have to come together to develop new technology. The new technology, in turn, will spin off new economy. The new economy replaces the old sectors and maintains the overall vitality of the economic activity of a country. In short, present IITs and new IITs must give emphasis on technology development and should develop a new methodology of innovation. It is strongly felt that new IITs will have the freedom and motivation to develop these new values.

The new IITs should develop appropriate paradigms of engineering education. The engineering science based education, presently practiced in many institutions, is strongly class-room oriented. Students are not confident of

working with their own hands in laboratories, studios and workshops. The spirit of apprenticeship is missing. The focus on “learning by doing” should be developed so as to motivate students for innovation and entrepreneurship. The concept of 4-i, Innovation, Implementation, Integration and Incubation, is necessary as a basis of engineering education. Such a paradigm shift can be considered along with the concept of Information Science Based Engineering Education. The present IITs have perfected the model of Engineering Science Based Education. One should preserve this concept. However, it is necessary to reform it further. The new IITs, it is hoped, will experiment with some of the new concepts and bring about a change in the philosophy of technical education.

It is interesting to note that during last decade of 20th century and the first five years of the present century, a dramatic rise in higher technical education has taken place in countries like China, Korea, Singapore and Japan. These developments are important for India’s global competitiveness. For example, during the period from 1995 till 2003, the number of Ph. D. admissions in China grew from 8,139 to 48,740. During the same period of 1995 to 2003, the Ph. D. admissions in India grew from 3000 to approximately 5000. For the year 2004, the number of scientific publications from China is reported to be 57,378. While for the year 2004, the number of publications from Korea happens to be 24,464 and for India, the corresponding number is 23,338. It is interesting to note that the registration of new doctoral students in science and engineering in the year 2003 from China is 9000, while the corresponding number for India is 4000. If this trend continues, India will be far behind its Asian neighbors in higher technical education. It is necessary to produce a significant number of graduates, in general, and post-graduates, in particular, for several branches of engineering sciences.

Education system in any country is linked with the pressure of the job or career market. There has been a phenomenal growth in the jobs required in IT sector. The NASSCOM report projects a need of 10,00,000 graduates by 2010. However, a peculiar situation has arisen in the country. All engineering graduates

get their training in any branch of engineering such as Civil Engineering or Aeronautical Engineering etc. However, right after graduation, they join jobs in IT sector. The need of this sector is so huge that new recruits are given a crash course, called Finishing School, and are inducted in the job hurriedly. In fact, many institutions can show that students after graduation are joining jobs in financial sector or IT sector. If high quality engineering jobs with appropriate financial compensation are made available then this trend will be altered. The new IITs should address the issue of developing appropriate engineering branches. These branches should be such that they provide the right kind of training to students. Also, students should make use of their training while searching for a job or a career.

The Government of India will have to review the entire supply chain of technical education from school education to job market in engineering. The Quality Improvement Program has successfully trained a large number of teachers from engineering colleges. This effort needs to be up-scaled so as to produce a cadre of quality teachers of engineering colleges. The concept of a Virtual Technical University is under consideration of Government of India. This institution will coordinate with existing technical institutions and train the existing cadre of teachers of engineering colleges. It is hoped that the post-graduate degree holders from existing and proposed IITs will be able to take up faculty positions in NITs and other engineering institutions. The shortage of quality faculty in NITs and other engineering colleges can be met successfully by establishing new IITs.

India will be preferred destination for engineering research and development in years to come. Several national and international R&D organizations will set up shops in India. Many international corporations such as General Electric, General Motors, Eaton Corporation, Honeywell, Pratt & Whitney, Airbus and Boeing are establishing their design and manufacturing R&D in India. The engineering services sector is also rising very rapidly. It is expected that the yearly turnover of this sector will rise to 25 - 30 billion US dollars in the

coming decade. The R&D as well as engineering services sectors will demand quality manpower comparable to world standards. It is hoped that new IITs along with the existing IITs will play a pivotal role in crystallizing the development of India as a hub of engineering R&D as well engineering services.

Engineering and science education as well as research is becoming increasingly interdisciplinary in nature. The present structure of departments in the university system as well as existing IITs has become so rigid that it is difficult to have faculty members with joint appointments to form an interdisciplinary group. Students are not allowed to credit courses in a flexible manner. Research projects with joint supervision from different departments are not carried out easily. This results in stifling the growth of new ideas. The proposed academic model of new IITs will showcase a new way of education and research. Once established, it can be spread around to other institutions and universities as well. In short, the spirit of boundary-less academics will be encouraged in these institutions.

Besides interdisciplinary research in an institution, it is also essential to promote linkages between IITs, industry and national research laboratories. With a consortium of such kind, it is possible to develop new products and technologies for societal issues of transportation, healthcare, education, communication, energy, water resources, environment, and materials. It is interesting to note the development of technology developed by a group of IITs, RDSO and industrial organizations. The new sensors as well as communication devices can transform the technological level of Indian Railway system. Such efforts need to be strengthened as well as up-scaled. It is hoped that new IITs will focus on technology development in the areas of national importance.

Design of a curriculum is always a challenging task. Design of an engineering curriculum is even more challenging for several reasons. An engineering discipline is always expanding its envelope of knowledge and practices. In order to cover the new areas as well as ensure that the core

knowledge is also retained in a curriculum, it becomes very difficult for an educator to decide about which areas need to be retained in a curriculum and which areas to be deleted from the curriculum.

Any professional curriculum has to give equal emphasis on Principles, Skills and Information.

A curriculum consists of core and professional components. It is usually expected that the core component will be about 50% in terms of number of courses and the professional component will constitute about 50%.

Academic Model of New IITs

The academic model of an educational institution is a critical element while designing the structure of that institute. The academic model of present IITs evolved from the university system as well as the system of engineering colleges. However, it must be said that IITs developed a strong base of engineering science based education. The concept of a core program followed by a professional program was unique at that time. The core program emphasized not only on natural sciences but also exposed students to humanities as well as social sciences. In other words, the foundation is very broad and rigorous in IIT system. The professional program has three components - compulsory courses, elective courses and project work. These courses are mainly from the department where a student is likely to specialize. Unfortunately, the present academic model does not promote interdisciplinary or cross-disciplinary learning. The present model does not emphasize synthesis and creativity elements. It is heavily titling towards training in analysis. The present model of IITs does not focus on personality development of the individual in terms of values, ethics, social sensitivities, and global awareness.

The new IITs, it is proposed, should promote a borderless academic environment. The distinction between different branches of engineering should be dissolved. The education and training should promote interdisciplinary learning. It should provide flexibility to a student to tailor a program according to his or her requirements. In short, it will provide a “buffet” of courses. A student can create his or her own dish. In order to ensure that such a change does not jeopardize the progress of a student in the professional world, it is proposed a branch will be assigned. However, each student will be able to design his or her curriculum with a major and a minor field of engineering or science. In other words, a student of Aeronautical Engineering can have Aerodynamics as major and Applied Mathematics as minor. A student of Computer Science can have Software Engineering as major and Product Design as minor. It is necessary to provide many choices to students. It allows students to think and take a decision. Hopefully, these decisions will not be influenced by parental pressures. Also, students will develop their individuality. At present, there is a tendency for students to copy each other’s identities. It is desirable that students should be able to make their own choices.

The second unique feature of the academic model of new IITs would be an emphasis on creativity. This is essential for inculcating a spirit of discovery and innovation. In order to develop such a spirit, it is proposed to have courses which will fuse technology and arts. These courses on creativity will be available both at the core level as well as professional level. The courses on product design and development will follow after the basic foundation of training in creativity has been imparted. It is said that most of the training in present IITs develop only the left side of the brain. The new IITs will hopefully look at the development of left side of the brain as well.

As an organization, it is proposed to have the concept of schools than departments. It will encourage academic staff to work together in an interdisciplinary environment. The following schools are proposed in every IIT.

- School of Engineering & Technology
- School of Design & Creative Arts
- School of Management
- School of Health Science & Technology
- School of Natural (or Basic Sciences)
- School of Humanities and Social Sciences

The approach of learning, in proposed IITs, will be by “doing”. Emphasis will be placed on development of skills in majority of courses. This approach along with training in creativity will create a new cadre of young graduates who will be able to design new products and develop new technologies. In order to develop skills, it is necessary to have a different kind of infrastructure. Besides class rooms, it will be necessary to have several laboratories or studios or workshops for students. The facilities at these places should encourage students to learn by themselves. Students should focus on a goal of acquiring a skill and practice extensively so as to not only learn the skill but imbibe it as a habit. In this fashion, the education is not simply giving information but is shaping the persona of students.

All educational institutions will soon have to compete at the global scale. With a decreasing trend of enrollment of students in western countries for engineering courses, it is expected that engineering education in Asia will become more critical. Students graduating from Asian institutions will be called upon to serve any where in the world. In order to meet such an eventuality, the academic program should be designed to develop a graduate who will be able to perform successfully on the world stage. For this goal, the communication skills of students should be excellent. The new IITs should ensure that the communication skills or soft skills are well developed in the academic programs both at undergraduate as well as postgraduate level.

The world is now a global village. The social forces are no longer local but exhibit global linkages. In order to understand one self as well as the world around an individual, it is necessary to have some education on aspects of life such as, for example, mind, ethics, values, jurisprudence, relations, society and time. All such courses should not be in discourse manner but should involve active skill development of students. It should be possible for students to visit different places and interact with society and learn some specific issues. It should be possible to understand from projects. Students should be trained on doing such projects either in a group or as an individual.

Project work will be very important in the proposed academic model. The project will be worth four courses as compared to worth two courses in the present IITs. It shows that learning through project is far more effective. In order to develop skills, each course will have some activities which may be in project form. Some projects will be carried out as a group and some projects will be carried out as an individual. It is expected that students will get some exposure to international scene in these projects. It may be possible to form a collaborative project with a student group from other country. The emphasis on international experience is desirable in an academic program

It has been observed that students of IITs do not develop interests in sports or culture. In order to appreciate the activities of sports and culture, students will be provided a card called Extra-curricular Performance Card. This card will be given along with the grade card of a student. This card will enlist the contributions and involvement of the student in sports and cultural activities during the entire four year period. It will be given due recognition. It is expected that students will develop a good portfolio of their extra-curricular activities.

The overall curriculum will consist of the following elements.

| | | |
|--------------------------------|---|------|
| Natural Sciences | 8 | 20 % |
| Engineering Sciences | 8 | 20 % |
| Humanities and Social Sciences | 8 | 20 % |
| Departmental Courses (Major) | 8 | 20% |
| Elective Courses (Minor) | 4 | 10 % |
| Project | 4 | 10 % |

Natural Sciences

Physics

Chemistry

Mathematics

Biology

Computational Science

Environmental Science

Material Science

Natural Science Electives

Engineering Sciences

Electronics Engineering

Communication Engineering

Engineering Informatics

Graphics & Simulation

Design & Manufacturing

Engineering Mechanics - I

Engineering Mechanics - II

Engineering Science Electives

Humanities and Social Sciences

Sociology

Psychology

Economics

Philosophy

English

Life Skills

Project Management

HSS Electives

Departmental Course (Major)

Elective Courses (Minor)

Project Work