Int. J. Engng Ed. Vol. 8, No. 1, pp. 22–35, 1992
Printed in Great Britain.

0742–0269/91 $3.00+0.00

The Present Status of Technical Education in India*

R. NATARAJAN†
N. V. C. SWAMY‡
Indian Institute of Technology, Madras, India

The interrelationships between science, technology, technical education and national development in the Indian context have been brought out through a discussion of several national policy statements. It is clear that the technical education system has a significant role to play in the fulfilment of national goals, which, therefore, have an impact on the goals of technical education applicable to India. The salient features of the Quality Improvement Programme and the role of the Indian Institutes of Technology are briefly highlighted. Several issues pertaining to the technical eduction system in India, ranging from specialization at the undergraduate level to the role of professional societies, are discussed in detail

INTRODUCTION

SCIENCE, technology and education are critical ingredients for national development. While science and technology influence the effectiveness of natural resources and capital utilization, education is concerned with human resource development. The principal requirement for imparting purposeful technical education is a clear articulation of goals and objectives. The national development objectives should enable the absorption of increasing proportions of the working population in modern types of activity and result in significant reduction in unemployment and underemployment. The objective of development is not simply to increase national income, but to ensure that such increse leads to improvement in the quality of life of the people.

ARTICULATION OF NATIONAL POLICIES

Particularly in the developing countries, science, technology and higher education have been entrusted with important responsibilities for responding to developmental needs. The Government of India has articulated national policies in each of these areas in specific terms in order to focus attention on the significant issues, prioritize resource allocation and, in general, to provide guidelines to planners and administrators.

The Scientific Policy Resolution

In May 1956, the Government of India set up a Scientific Advisory Committee to the Cabinet (**SACC**) and charged it with the responsibility of advising the Cabinet in the 'formulation and implementation of Government's scientific policy'. The Scientific Policy Resolution was officially enunciated on 4 March 1958. The first paragraph clearly sets forth the emerging role envisaged for science, both basic and applied, and indicates the Government's intention to support science and technology in order to 'secure for the people of the country all the benefits that can accrue from the acquisition and application of scientific knowledge':

> The key to national prosperity, apart from the spirit of the people, lies, in the modern age, in the effective combination of three factors, technology, raw materials and capital, of which the first is perhaps the most important, since the creation and adoption of new scientific techniques can, in fact, make up for a deficiency in natural resources, and reduce the demands on capital. But technology can only grow out of the study of science and its applications.

In 1968, the SACC was replaced by the Committee on Science and Technology (**COST**) so as to encompass the field of technology as well. In 1971, COST in turn was replaced by the National Committee on Science and Technology (**NCST**), with the specific mandate for preparation, evaluation and updating of national scientific and technological plans.

The Industrial Policy Resolution

The Industrial Policy Resolution dates back to 1956, and provides guidelines for the implementation of the policy related to import of technology and foreign investment. This policy has undergone a number of changes, but it basically recognizes the necessity for continued flow of technology in areas not adequately developed, and demands that Indian firms that are to import foreign technology

* Paper accepted 1 August 1991.
† Professor of Mechanical Engineering; Chairman, Centre for Continuing Education.
‡ Director.

should set up in-house R&D facilities so that imported technology is properly adopted and assimilated.

An Approach to S and T Plan

The NCST brought out a policy document entitled 'An Approach to S and T Plan' in 1973, as a first important step towards the systematic planning of science and technology for development. This document reflected the sectoral needs, areas of thrust and possible avenues for extending known scientific and technological skills. The main emphasis was placed on interdisciplinary and multi-institutional projects, as well as on sponsored projects and in-house R&D in industry. Three of the most important features of this S and T Plan were:

1. Laying as much emphasis on the development of engineering, design and fabrication skills as on the development of process/product technology.
2. Making the existing S and T infrastructure more effective through the provision of additional facilities, rather than creating new organizations.
3. Emphasizing rural development.

The S and T Plan served to provide a useful check-list of programmes and projects that needed to be undertaken. However, in the absence of an assigned responsibility and a mechanism for prioritization, identification of tasks and projects, and allocation of resources to appropriate institutions for their implementation, monitoring and review, the 1973 NCST Plan remained largely a plan. Nevertheless, the Plan served to create an awareness about the science and technology inputs that had the potential to fulfil the sectoral economic objectives. As a part of this process, separate science and technology budget heads have been created in various central ministries, and Special Committees for Implementation of Projects (**SCIP**) have been set up for a few of them.

The NCST was reconstituted in July 1977, with a major change that the mandate for science and technology planning was dropped; the NCST emphasized the need for application of science and technology, particularly towards rural development, and proposed a Technology Policy Statement, with adequate emphasis on rural development, and suggested steps to enable science and technology planning to become an integral part of socio-economic planning.

The Technology Policy Statement

Subsequently in 1983, a Technology Policy Statement was announced, with the basic objectives of 'development of indigenous technology and efficient absorption and adoption of imported technology appropriate to national priorities and resources'. It stated that:

> special attention will be given to the promotion and strengthening of the technology base in newly emerging and frontier areas such as information and materials sciences, electronics and bio-technology. Education and training to upgrade skills are also of utmost importance. Basic research and building of centres of excellence will be encouraged.

It recognized that 'all of this calls for substantial financial investments and also strengthening of the linkages between various sectors (educational institutions, R and D establishments, industry and government machinery)'.

The Technology Policy Statement stressed efficiency and productivity, the spirit of innovation and invention as the driving force behind all technological change, enhancement of traditional skills and capabilities, ensuring timely availability, modernization to prevent obsolescence, design engineering for the translation of know-how to commercial production, engineering consultancy, a judicious mix of indigenous and imported technology, etc.

The National Education Policies

Since independence, several working groups, commissions and documents have recognized that the achievement of economic and social development can be facilitated and expedited through proper education, and that human resource development has a multiplier effect on the utilization of all other resources. The concept of education as an investment in development has now been accepted, and in 1966 the Report of the Education Commission (1964–66) referred to education as the only instrument of peaceful social change.

This report identified equity, quality and relevance as of particular significance in planning the development of the education system. It provided guidelines for the design of the university-level education system:

> A system of university education which produces a high proportion of competent professional manpower is of great assistance in increasing productivity and promoting economic growth. Another system of higher education with the same total output but producing a large proportion of indifferently educated graduates of arts, many of whom remain unemployed or even unemployable, could create social tensions and retard economic growth. It is only the right type of education, provided on an adequate scale that can lead to national development; when these conditions are not satisfied the opposite effect may result.

The first National Education Policy was formulated in 1968, and 'envisaged a radical transformation of the education system to relate it more closely to the lives of the people, provide expanded educational opportunities, initiate a sustained intensive effort to raise the quality of education at all stages, emphasize the development of science and technology, and cultivate moral and social values'. The goal of this education policy was 'the creation of an ethos that would produce young men and women of character and ability committed to national service and development'.

It was also envisaged at the time of formulation of this Policy that it would be followed by a 'five yearly review of progress and working out of new policies and programmes'. Accordingly, at the time of formulation of every new five-year plan, a review has been undertaken to assess the shortcomings and achievements of education, and decide upon the programmes for the next five years. While these reviews have been quite useful, it was felt in 1985 that a mere review and minor modifications of the existing framework would not be enough. It was recognized that 'those who are being born now would be entering a world which would offer opportunities unprecedented in the history of mankind to those who are equipped to cope with the future challenges and the accelerating pace of change'.

The Ministry of Education prepared a document in August 1985 entitled 'Challenge of Education—a policy perspective', containing 'an overview of the state of education and pointers to the direction of future initiatives, based essentially on the views and suggestions from educational planners, teachers, students, parents, intellectuals and citizens interested in education'. The document was widely circulated and discussed in several fora throughout the country, and resulted ultimately in the formulation of the National Policy on Education—1986 (**NPE-1986**).

As far as technical education is concerned, the 1968 Policy stressed its importance, but dealt with it briefly. The 1986 document, while recognizing the significant contributions made by technical education to India's economic development, identified several problems requiring immediate attention.

The first issue related to the 'obsolescence of machinery and equipment, and the non-availability of the wherewithal to deal with the training and research requirements in respect of new technologies'. It was stressed that the rapid modernization that the industrial sector had to bring about in order to survive intense international competition could only materialize if measures are taken expeditiously to provide the technical education system 'with relevant equipment as and when required, reorient and enrich the curricula, augment the human resources with new expertise and prepare appropriate instructional materials, textbooks and educational technologies'. It was also recognized that in addition to 'the highly trained professionals, technicians are equally important since they are the operational instruments for raising industrial productivity'.

Another major problem identified was the inability of the technical institutions to attract good teachers. On average, 20–30% of positions were vacant in the degree and diploma level institutions—a result of the unattractive salaries and perks, when compared to industrial careers. The work ethos in the majority of institutions was deplorable, the industry–institution interaction, which was 'so crucial for ensuring relevant quality and cost-effectiveness', remained weak, and industrial investment in research undertaken by the technical institutions continued to be negligible.

In the Indian context, wherein technology had also to make a major contribution to rural development, technical institutions did not concern themselves vigorously with 'the application of modern technology for the benefit of the common man in rural areas'.

There was a wide variability in standards between different different types of technical institutions, with the Indian Institutes of Technology (**IITs**), and the Regional Engineering Colleges (**RECs**) and the State Engineering Colleges (**SECs**) occupying the apex of the pyramid. Many institutions languished for want of financial resources, which resulted in poor-quality manpower being turned out into the employment market. 'The linkage of technical education with manpower planning remained weak'. With the Technology Policy Statement envisaging rapid modernization of Indian industry, manpower needs had to be identified and eductional/training facilities created in collaboration with industries in the public and private sectors. 'The quality improvement and faculty development programmes, as well as application-oriented research needs, had to be promoted much more extensively.'

It was also pointed out that management education was 'another area of great importance in raising productivity'. In view of the fact that management education has tended to 'focus on the requirements of the private corporate sector and that too in certain selected fields', it was recommended that the academic fees should be enhanced to realize the real cost of education.

It was also necessary to 'recognize the relevance of management education in all sectors including such areas as agriculture, rural development, education, health, social welfare etc., so as to generate a positive culture of involvement in developing management alternatives and models to suit the requirements in these fields'. In addition, 'the networking arrangements between the institutes of management, university departments of business administration and public sector and public and private institutions' had to be strengthened so as to improve the quality of management education all over the country.

The National Policy on Education—1986

For the first time, the NPE—1986 brought technical and management education together, in view of their close relationship and complementary concerns. It laid emphasis on the following areas:

- Reorganization of technical and management education, taking into account the anticipated scenario by the turn of the century.
- Greater induction of improved technologies into

the infrastructure and services sectors as well as the unorganized rural sector.

- Strengthening of the Technical Manpower Information System.
- Promotion of continuing education.
- Organization of computer literacy programmes at the school stage.
- Reorganization of technical and management education programmes on a flexible modular pattern based on credits, and with provision for multipoint entry.
- Appropriate formal and non-formal programmes of technical education for the benefit of women, the economically and socially weaker sections, and the physically handicapped.
- Training in entrepreneurship for self-employment.
- Focusing on research and development for improving present technologies, developing new indigenous ones, and enhancing production and productivity.
- Setting up suitable systems for monitoring and forecasting technology.
- Networking relationships between institutions at various levels and with the user systems.
- Initiation of steps for promoting efficiency and effectiveness at all levels, and for achieving cost-effectiveness and excellence.
- Coordination by the Ministry of Human Resources Development (**MHRD**) of the balanced development of engineering, vocational and management education as well as the education of technicians and craftsmen.
- Granting of statutory authority to the All India Council for Technical Education (**AICTE**) for planning, formulation and the maintenance of norms and standards, accreditation, funding of priority areas, monitoring and evaluation, etc.
- Maintenance of standards by curbing the commercialization of technical and professional education.

The Programme of Action

It has been repeatedly felt and pointed out that Indians are quite proficient in drawing up plans and plan documents, but are quite deficient in implementation strategies and procedures. Keeping this in view, the Government of India, MHRD, followed up the NPE—1986 with a 'Programme of Action' to implement the Policy.

In the first place, 23 task forces were constituted and each was assigned a specific subject covered by the NPE. Eminent educationalists, experts and senior representatives of central and state governments were associated with these task forces. The task forces were requested to examine the present situation in respect of the subjects assigned to them, and to elaborate the implications of the specific statements contained in the NPE. The task forces were also expected to specify the actions that would be necessary and indicate the broad targets and the phasing of the programmes, and also the broad financial implications with reference to each phase.

As far as technical and management education is concerned, the following salient features were highlighted:

- A more purposeful role for the AICTE in controlling the unregulated expansion of technical education without reference to the overall needs of the economy and quality.
- Strengthening of the national technical manpower systems for more effective planning of technical and management education, with assistance from the lead centre at the Institute of Applied Manpower Research and 21 other nodal centres in technological institutes and other agencies in the states.
- Following the major emphasis laid on consolidation, improvement of quality and standards of technical education, postgraduate engineering education and research, during the third, fourth and fifth five-year plans, the present and future thrusts were expected to be in the areas of computerization, new emerging technologies, application of science and technology to rural development, and continuing education.
- Special emphasis on education of technicians.
- Bringing about a positive attitudinal change among students towards self-employment and equipping them with relevant skills for entrepreneurship.
- Special polytechnics for women, along with hostel facilities.
- Network scheme between all the technical institutions at different levels, between the technical institutions and other institutions in the education sector, and between educational institutions and R&D organizations/institutions.
- Modernization of laboratories and workshops.
- Strengthening of library facilities and services, taking into account recent developments in the field of educational and information technology.
- Faculty development schemes in order to make their role more effective.
- Shifting of focus from generation of new knowledge to the application of knowledge for enhancing production and productivity.
- Setting up a Board of Accreditation to prescribe guidelines and norms for the accreditation of programmes and institutions, and for promoting excellence.
- Introduction of appropriate legislation for vesting the AICTE with statutory authority to play its role adequately and effectively.
- Initiation of action for formulation of guidelines for identifying and awarding academic, administrative and financial autonomy to technical and management institutions, and prescribing norms of accountability.
- Support will be offered to several institutions to offer programmes and courses in computer education at different levels, and also to undertake teacher training and software development.

- State departments responsible for technical and management education will establish/strengthen state-level curriculum development cells.
- Technical and management programmes at degree and diploma levels would be restructured on a flexible modular pattern based on a credit system and with provision for multipoint entry.
- Opportunities for technical education for women at all levels will be considerably increased; women's access to technical education will be improved qualitatively and quantitatively.
- The AICTE will set up a Board of Studies for continuing education and distance learning.
- The AICTE will formulate guidelines for the promotion and planning of industry–institute interaction.
- Effective linkages will be established between technical education and general sectors.
- Suitable schemes will be formulated by the AICTE for modernization and removal of obsolescence, and infrastructure development.
- The central government will constitute technology watch groups in higher institutions of learning in each state.

The AICTE Act

Recently in 1988, the AICTE has been vested with statutory authority for planning, formulation and maintenance of norms and standards, funding of priority areas, monitoring and evaluation, and for ensuring the coordinated and integrated development of technical and management education.

The AICTE Act defined 'technical education' to include programmes of education, research and training in engineering, technology, architecture, town planning, management, pharmacy, and applied arts and crafts.

The major powers and functions of the Council included the following:

- Forecasting the required growth and development in technical education.
- Coordinating the development of technical education in the country at all levels.
- Promoting innovations, and R&D in established and new technologies; generation, adoption and adaptation of new technologies to meet developmental requirements; and overall improvement of educational processes.
- Formulating schemes for promoting technical education for women, and handicapped and weaker sections of the society.
- Promoting an effective link between the technical education system and other relevant systems, including R&D organizations, industry and the community.
- Evolving suitable performance appraisal systems for technical institutions and universities imparting technical education, incorporating norms and mechanisms for enforcing accountability.
- Formulating schemes for the initial and in-service training of teachers and for setting up centres for staff development programmes.
- Laying down norms and standards for courses, curricula, physical and instructional facilities, staff patterns, staff qualifications, quality of instruction, assessment and examinations.
- Fixing norms and guidelines for charging tuition and other fees.
- Granting approval for starting new technical institutions and for introducing new courses or programmes in consultation with the agencies concerned.
- Laying down norms for granting autonomy to technical institutions.
- Advising central government regarding professional societies in the matter of examinations and award of membership certificates.
- Taking all necessary steps to prevent commercialization of technical education.
- Providing guidelines for admission of students to technical institutions.
- Inspecting or causing to inspect any technical institution.
- Withholding or discontinuing grants in respect of courses and programmes to those technical institutions that fail to comply with the directions given by the Council within the stipulated period of time.
- Declaring technical institutions at various levels and types offering courses in technical education fit to receive grants.
- Creating positions of professional, technical and support staff based on requirements.
- Advising the UGC for declaring any institution imparting technical education as a deemed University.
- Setting up a National Board of Accreditation to conduct periodically evaluation of technical institutions or programmes on the basis of guidelines, norms and standards specified by it, and to make recommendations regarding recognition or derecognition of the institution or programme.

At the second meeting of the AICTE held in July 1990, merit-based and uniform guidelines for admission to engineering colleges and polytechnics have been recommended. It has been suggested that entrance tests in physics, chemistry and mathematics at plus-2 level should be conducted by all states, and that admission in reserved categories should be strictly on the basis of merit as prescribed.

SOME STATISTICAL INFORMATION

There are essentially four levels of technical education in the country. The industrial training institutes provide vocational-type technical training in a wide range of trades; the polytechnics prepare candidates for diplomas, and the engineering colleges provide technical education leading to baccalaureate degrees. Postgraduate education and research leading to Ph.D. and M.E./M.Tech./ M.Sc.(Engg.) degrees are provided by a small number of institutions.

There are different types of degree-level engineering institutions. The five IITs, four Indian Institutes of Managements (**IIMs**) the Indian Institute of Science (**IISc**) and the NITIE are considered to be national institutes [1]. There are in addition, 16 RECs, five technological universities, four Technical Teacher Training Institutes (**TTTIs**), one for each region, and 23 fine arts and crafts colleges. Table 1 gives the state-wide distribution of the other types of technical institutions. While there has been uncontrolled growth of engineering institutions over the past few years, particularly in the states of Andhra Pradesh, Karnataka, Maharashtra and Tamil Nadu, the AICTE Act, which was accorded statutory status in February 1988, provides a mechanism for weeding out those without adequate infrastructure and faculty. Regional committees have been set up by the AICTE to inspect the existing non-government colleges and make recommendations for effecting improvements, or if the situation warrants it, closure of these institutions. It is envisaged that the Accreditation Board will make periodic inspections of all the institutions, both government and non-government, to ensure the delivery of good quality engineering education.

INVESTIGATION OF THE GOALS OF ENGINEERING EDUCATION

There have been a few systematic efforts to articulate the goals of engineering education, particularly in the USA and the UK. In India, a ministry-sponsored Delphi study was conducted in 1976 [2] on the future goals of basic engineering education. The principal objectives of this study were threefold:

1. To identify the goals of engineering education in India for the coming decade.
2. To reach a reasonable consensus on the priorities of these goals for the basic (undergraduate) engineering education programme.
3. To examine the effectiveness of Delphi as a tool for increasing consensus on engineering education goals and priorities.

The study took note of the quantitative expansion in engineering education in the country during 1947–1977:

- Number of engineering colleges 38 to 143.
- Admission capacity 2940 to 25,000.
- Faculty positions 1500 to 12,000.

With the emergence of the country as an independent nation, there has been a significant quali-

Table 1. State-wise distribution of technical institutions [1]

State	Degree-level institutions		Diploma-level institutions		
	State engineering colleges	Unaided engineering colleges	Govt. polytechnics	Unaided polytechnics	Women's polytechnics
1. Andhra Pradesh	14	17	42	19	17
2. Andaman & Nicobar	—	—	1	—	—
3. Assam	4		7	—	1
4. Bihar	7	—	17	—	5
5. Chandigarh	4	—	1	—	1
6. Dadra Nagar Haveli	—	—	1	—	—
7. Delhi	6	—	8	—	3
8. Goa	2	—	5	—	—
9. Gujarat	14	—	25	—	2
10. Haryana	2	—	10	—	2
11. Himachal Pradesh	—	—	3	—	1
12. Jammu & Kashmir	—	—	2	—	1
13. Karnataka	17	36	34	125	5
14. Kerala	9	—	23	—	5
15. Madhya Pradesh	11	—	30	—	5
16. Maharashtra	20	55	44	99	3
17. Manipur	—	—	1	—	—
18. Meghalaya	—	—	1	—	—
19. Mizoram	—	—	1	—	—
20. Nagaland	—	—	1	—	—
21. Orissa	3	—	8	—	3
22. Pondicherry	1	—	1	—	—
23. Punjab	5	—	13	.	1
24. Rajasthan	5	—	14	—	5
25. Tamil Nadu	15	27	45	75	10
26. Tripura	1	—	1	—	—
27. Uttar Pradesh	14	—	66	—	7
28. West Bengal	11	—	27	—	2
Total	165	135	432	318	79

tative difference in the job requirements and work ethos of graduate engineers, with enhancement and upgrading of responsibilities from mere maintenance and operation of complex technological systems to their planning, design and production. While methodical and repetitive work, characteristic of earlier occupations, demanded certain manual skills, a common-sense approach to work and pride in manual labour, interdisciplinary work in engineering has today become a necessity, along with skills and knowledge in advanced computing, data management, diagnostics, automation, materials technology, energy systems, etc. Effective teamwork is essential for undertakng major projects and goal-oriented missions.

On the other hand, with India's large population, which is experiencing an uncontrolled (and uncontrollable) growth, 'the insecurity and threat the machines pose to jobs have led to questions about the validity of adopting modern technology as a development tool'.

In 1974, on the recommendation of the AICTE, a Joint Committee of the Council and the University Grants Commission was set up to review the entire system of engineering education at the first degree level; the major issues under study were long-term goals, curriculum design and development, institutional administration, continuing education, the role of computers and laboratories in engineering education, etc.

The Delphi study investigated the importance attached to 40 national goals of engineering education (which were identified by 109 Indian experts drawn primarily from industry, R&D organizations and engineering colleges), as perceived by the panelists, through four rounds of Delphi. The goal areas were divided into three groups, and the ranks and priorities were established for the national goals in each group; the first four items in each group are listed below:

1. *National tasks*:
   - energy sources and systems;
   - food production and processing;
   - industrial development;
   - rural development.
2. *Professional skills*:
   - analytical skills;
   - workshop and fabrication skills;
   - entrepreneurial skills;
   - managerial techniques.
3. *Professional attitudes*:
   - professional integrity;
   - interest in updating professional skills and knowledge;
   - willingness to work in a team towards common objectives;
   - a sense of professional pride.

'These results indicate in broad terms the direction which undergraduate engineering eduction should take in India during the coming decade.' One striking feature is that industrial development, which has intuitively been the foremost long-term goal of undergraduate engineering education for 30 years, is relegated to third rank; and rural development, which had not explicitly received any thrust in the past, is now ranked fourth among a total of 17 national tasks.

The study has also examined the nexus between educational and national development goals; in particular, whether the goals of engineering education should be linked to national development goals. There is first the problem of identifying national goals: should they be 'the national goals stated in broad generalities in the Indian Constitution or the resource-oriented, time-bound targets detailed in the Planning Commission Reports?' Secondly, 'the national goals of a society do not have the same degree of permanence for professional education as do professional skills'. Thirdly, the national priorities are likely to change with changes in government and policy makers. The study cautions that 'the needs and aspirations of the individual are likely to be overlooked when educational goals are linked to national development'. The authors concluded that the setting of goals should ultimately depend on the value judgements of 'national advice communities', and on community acceptance at state and local levels. It is recommended that policy-makers should provide periodic forecasts of manpower requirements, at the regional and national levels, and at the degree/diploma/vocational levels, to enable the engineering education system to respond both quantitatively and qualitatively.

The study has also compared the American and Indian goals. While the 1968 ASEE Goals Committee placed great emphasis on professional skills, attitudes, individual needs and the challenge of accelerating technological change, the Delphi study identified, in addition, several goals relevant to the Indian context, emphasizing the socialistic pattern of society and commitment to planned economic development.

THE QUALITY IMPROVEMENT PROGRAMME

The Quality Improvement Programme (**QIP**) was launched by the (then) Ministry of Education in 1970 as a means of upgrading the expertise and capabilities of engineering college teachers in the country. The QIP has three components:

1. It provides opportunities for serving teachers in the AICTE—recognized engineering colleges to improve their qualifications and obtain Ph.D. or M.Tech. degrees in selected institutions and departments in the country.
2. It provides opportunities for teachers to participate in short-term courses organized by selected institutions, during the summer and winter vacations, in order to combat obsolescence, get introduced to emerging areas, obtain refresher courses, learn about teaching and learning methodologies, etc.

3. Curriculum development cells have been set up in selected institutions for upgrading curricula, examination reforms, preparations of teaching resource materials, etc.

The QIP has proved to be one of the most successful programmes launched by the government of India. It has enabled a large number of faculty members from engineering colleges to upgrade their qualifications, which has resulted in the widespread diffusion of the R&D culture, and improvement in the quality of instruction. There is a continuing effort to improve the quality of technical education in the country, with participation from a large number of engineering teachers. While more innovative programmes need to be initiated to deal with newly emerging challenges, there is cause for a feeling of satisfaction with the success achieved.

THE ROLE OF THE INDIAN INSTITUTES OF TECHNOLOGY

The five IITs were set up by an Act of Parliament as 'Institutes of National Importance', a little more than 30 years ago in the following sequence:

- IIT Kharagpur 1950
- IIT Bombay 1957
- IIT Madras 1959
- IIT Kanpur 1960
- IIT Delhi 1961

They were conceived to act as leaders in technology innovation, train the necessary manpower and promote state-of-art technology in the country. Their role was to enhance the country's techno-economic strength and technological self-reliance. The Government's decision to establish these institutes *de novo* rather than strengthen the institutions already existing at that time was based on the premise that these new institutions needed to develop their own specific culture for promoting excellence.

In response to the higher expectations of excellence in their achievement, performance and commitment to the nation, and liberal financial allocation from central government, the IITs have maintained an excellent track record. Their Joint Entrance Examination (**JEE**) system, together with their excellent reputation, has enabled them to get the best students for their undergraduate courses. As autonomous institutions, the IITs have been able to review periodically their courses of study and method of evaluation in order to offer the best instruction and bring out the best from the students. With well-equipped laboratories and highly qualified and motivated faculty, the IITs have been able to pursue academic research of international standard, take up sponsored research projects of direct relevance to national needs, and offer consultancy services to Indian industry. There is, nevertheless, scope for improvements in order to enable them to realize their full potential.

The major contributions of the IITs are listed below:

- Before the late 1950s, a survey of the technical education scene in India reveals a predominance of undergraduate education and training in various universities, with very little emphasis on post-graduate education or R&D. The setting up of the five IITs has served to usher in a new culture in technical education by providing a quantum leap in the quality of instruction, R&D, and interaction with industry. The IITs have thereby contributed to a high degree of technological self-reliance.
- Most of the doctorate-level research in engineering is confined to the IITs. Over the period 1974–84, 1670 scholars in engineering (and 1582 scholars in sciences) have obtained their doctoral degrees from the IITs.
- High-quality publications in reputed international and national journals have been the hallmark of the IIT system. These have served to project India's national image onto the international scene in the areas of science and technology.
- A major proportion of post-graduate education in the country, at the M.Tech. level, is provided by the IITs. Approximately 60% of all M.Tech. graduates in the country are produced by the IITs (about 15% are produced by the IISc).
- Prior to the establishment of the IITs, and the initiation of the QIP in 1971, there were very few teachers in technical institutions with post-graduate qualifications. The unqualified success of the QIP schemes, as a result of which there are very few teachers without post-graduate qualifications in the technical institutions, is mainly due to the IITs (and the IISc and the University of Roorkee). Under the QIP scheme, over 1200 teachers have obtained their Ph.D. or M.Tech. and have returned to their respective institutions.
- In view of the high credibility established by the IITs, they have been able to attract a large number of engineers from industry, public sector utilities and R&D establishments for postgraduate and research programmes.
- The IITs offer, on a regular basis, all through the year, continuing education programmes in hi-tech areas for the benefit of practising engineers of industries and R&D institutions. On average, approximately 100 programmes are offered annually in the five IITs.
- The IITs have played a pioneering role in establishing viable linkages with industry, which are gaining in strength. Separate centres have been established to promote and accelerate these activities.
- Almost all government departments and private industries have sponsored goal-oriented R&D programmes at the IITs. On average, each IIT receives sponsored research projects to the value of about Rs. 50 million annually.

- The faculty of the IITs have been utilized as a think-tank by several national bodies.
- Several countries (e.g. USSR, USA, Canada, Egypt, FRG, France, UK, Japan) are coming forward to collaborate with the IITs.
- The HRD has entrusted the IITs with the responsibility of providing guidance, advice and assistance to selected engineering colleges in the respective regions, under network schemes, in order to assist in their institutional and laboratory development programmes.
- All the IITs have been entrusted with the responsibility of curriculum development in different branches of engineering. Model curricula have been developed and disseminated to all engineering colleges. Centres of Educational Technology have also been set up in the IITs in order to develop and disseminate multi-media instructional packages.

UPGRADING OF POLYTECHNIC EDUCATION

The polytechnic education system has a very important role to play in the national technological scene. The professional inputs from the diploma holders in the different disciplines are essential for productive industrial activities. While efforts have been undertaken over the years to strengthen this system, for example, by providing in-service training to the polytechnic teachers at the four regional TTTIs in Madras, Bhopal, Chandigarh and Calcutta, leading educationalists and industrialists have expressed the view that the standard of polytechnic education in the country is inadequate to meet the rising need for competent, middle-level technical manpower, and that a thorough overhaul of this system is long overdue.

In this context, the Government of India has sought a soft loan of about Rs. 7000 million from the World Bank for implementing, in eight states of the country, a Project for the Upgradation of Technician Education. The Project envisages (i) capacity expansion, involving the starting of new polytechnics, construction of buildings, starting of new courses in engineering areas, etc.; (ii) quality improvement, involving purchase of modern equipment to upgrade laboratory facilities, setting up learning resource development centres, computer centres and curriculum development centres, strengthening audiovisual and reprographic centres, etc.; and (iii) efficiency improvement, involving steps to streamline the examination system, setting up of industry–institution interaction cells, setting up maintenance centres in the Regional Directorates, setting up monitoring and manpower planning cells in the Directorates, etc.

Edcil (Educational Consultants India), New Delhi, are the consultants to the Government of India for the execution of the Project. The TTTIs have also been requested to provide their expertise in the implementation of the project, which will be operational for a period of 5–6 years with effect from April 1990, and is expected to bring about a remarkable transformation in the polytechnic education system in the country.

ANALYSIS OF SOME ISSUES

The genealist vs. specialist dilemma

A basic problem is concerned with the question of whether the thrust should be in producing generalists or specialists. If 'appropriate' technology is considered to be more beneficial than advanced technology for developing countries, then the majority of engineers should be educated as generalists rather than as specialists. Courses, particularly at the undergraduate level, should be offered in broad disciplines, and not in narrow specializations. For national development, it is found that people with a broad background and with specialization in more than one discipline tend to appreciate the need for adaptation.

As science and technology are developing rapidly, there is a need to specialize. Both expansion and specialization are necessary, and the problem is that if India develops a broad curriculum to fulfil the current needs of the country, how do we find the time to educate the students to become proficient in their own field, so that India does not lag behind the rest of the world, and is not always following the lead given by other countries?

Rational and optimal planning for manpower development

In the absence of reliable estimates of the numbers, levels and types of engineers required in the short, medium and long term, indiscriminate expansion and diversification will only result in large-scale frustration due to unemployment and underemployment. There are several examples of sudden but temporary demand in some disciplines, which have caused distortions in the technical education system; for example, the creation of admission capacity for aerospace engineers in the 1950s, for energy engineers in the late 1970s, and for computer engineers in the 1980s.

A sound database on manpower needs, both in relation to numbers and disciplines, is a prerequisite for optimal allocation of resources. In most countries, this aspect is fraught with practical and procedural difficulties.

In order to plan the education system in terms of intake, content and structure, it is necessary to estimate the demands for such output in quantitative and qualitative terms. These manpower demand estimates are subject to adjustments due to economic uncertainties and the changing nature of the perceptions, attitudes and expectations of the different segments of society. A mismatch between manpower demand and the development of higher education results in unemployment and underemployment. Unless a continuous feedback loop is established in this dynamic process, significant unemployment and underemployment will lead to major discontent and social and economic crises. An analysis of the extent of match/mismatch will bring out the strengths and shortcomings of the education sytem, not only quantitatively but also qualitatively.

Education for employment

The close correspondence between the labour market and the higher education system is at the heart of the manpower planning process. The conditions of work, recruitment and promotion policy of the employment market significantly influence the type of qualifications that employees must possess.

There is a reciprocal relationship between educational planning and manpower planning. The policy for human resource development in the context of national development requires the analysis of the skills needed for the various activities to be performed in different sectors of the economy. Conversely, the output of the education system, in terms of the various skills and knowledge imparted, has to be known for proper utilization of the human resources it generates.

There is a sequential relationship between education—particularly vocational education or training—and employment. The former is expected to provide the preparatory phase for employment. Any mismatch is compensated for by on-the-job training.

An analysis of the distribution of enrolment among science and technology and art-based subjects reveals some interesting factors. While the former perform most of the productive activities in the economy, the latter are mostly involved in the service sector. In most of the developing countries, when social pressures lead to the expansion of higher education without a proportionate increase in the share of the budget, expansion is resorted to in areas where the costs are minimal. This leads to a much faster rate of increase in enrolments in the arts-based courses. As against this, the economic development of the country needs more science and technology graduates.

In most Asian countries, it has been established that expansion in higher education has ignored the problem of graduate employability. Contrary to the belief that a significant proportion of them pursue higher education for its own sake, it is established that students pursue higher education for better employment opportunities.

Entrepreneurship development

In a sense, industrial entrepreneurship has come of age in India. The severe problem of educated unemployment, the willingness of the present-day youth to undertake self-employment, a suitable atmosphere for small-scale business in the country, and the tremendous fillip given by both the central and state governments to prospective entrepreneurs through various schemes, have all contributed to this. On their part, the universities have been trying to include suitable instruction in industrial engineering, industrial management, business management, finance, marketing, etc. Institutions have been esablished throughout the country, offering training and education at all levels in these fields.

Students tend to regard 'business' and 'profit' as dirty words. To most of them business ethics are not as high as their own personal standards. They feel that they have to compromise too much between their personal standards and business values. There is no doubt some truth in this, as several entrepreneurs have experienced on entering the business world of licenses, certificates, loans, orders, procurement of raw materials, etc. Nevertheless, those entering business should take this up as a challenge, and should have the conviction that they would contribute significantly to improvement of the existing situation. They should enter the business world with anticipation, enthusiasm and confidence. On the whole, present-day entrepreneurs have a number of things going for them, and the chances of success in their ventures are high.

Accreditation of institutions and programmes

While quantitative expansion is relatively easy to plan for and achieve, quality control and quality assurance are very difficult to incorporate. There has been, over the past decade, an uncontrolled growth and mushrooming of engineering colleges in several parts of the country, in response to a popular demand for professional education. With the government unable to finance these institutions, they have relied on the so-called 'capitation fee' and high fees. However, not all institutions have utilized the funds for provision of infrastructure and hiring of qualified staff.

In order to check this undesirable growth, which has eventually resulted in large numbers of unemployed (and unemployable) graduates, and also to provide a means of monitoring the performance and standards of all institutions, the NPE—1986 had envisaged the setting up of an Accreditation Board, under the overall control of the All India Council for Technical Education. A corresponding Accreditation Commission has been set up by the University Grants Commission for non-technical education areas.

The National Accreditation Board for Technical Education (**NABTE**) has drawn heavily from the structure and experience of the well-established Accreditation Board for Engineering and Technology (**ABET**) of the USA. The rationale for assessment of both the individual programmes and the entire institution, for the accreditation of individual programmes, is that the institution is not just the sum of the departments or programmes; it includes, in addition, physical factors, such as central service facilities (library, computer facilities, instrumentation, maintenance, etc.) and psychological factors, such as academic atmosphere, traditions, attitudes, image, reputation, etc., which give an institution its 'personality'. The overall evaluation procedure is based on both quantitative and qualitative characteristics, and is ultimately subjective.

While the ABET accreditation is voluntary, and institutions seek accreditation for their programmes in order to maintain their reputation and public image, the NABTE is proceeding on the basis of mandatory accreditation. The aims are to 'tone up' existing institutions and also to curtail the mushrooming of poor-quality institutions. The UGC concept proposes to use accreditation as a necessary qualification for eligibility to receive government funds.

While the ABET accreditation is performed principally by and through professional societies, which have considerable clout, credibility and co-ordination, the NABTE accreditation will involve representatives from well-established professional societies, but will be administered by the AICTE.

Development of engineering teachers

One of the most important factors determining the quality of engineering education is the quality and attitudes of the faculty. The development of a competent engineering teacher is a complex process, and requires detailed planning and unwavering commitment. Engineering is a profession and can only be taught effectively by faculty who have experience of the functions and responsibilities of professional engineers. Selection and retention of qualified teaching staff are central to this. Effective development of an engineering teacher is a long process that comprises several stages. Unfortunately, the process is often limited to the acquisition of a research-oriented doctorate. Such important elements as practical experience and pedagogical training are frequently omitted. Both the individual and the institution should formulate plans, establish clearly the role the individual has to play in the institution's plan and then review developments periodically for progress and possible modification.

It is currently estimated that about 30% of teaching positions are vacant in engineering institutions, whereas there is widespread unemployment of certain qualified/trained personnel. If the best of the crop shies away from teaching, how can we hope to deliver high-quality education? If we want to make teaching in engineering institutions an attractive profession, it is imperative that the overall image of the faculty is enhanced in the eyes of society. The significance of their role in national development must be abundantly recognized, and they must be actively involved in the determination of policies and decisions concerning technical education at the highest level.

In order to be effective, the faculty need to have continuous co-operative linkages with industries and government agencies and research laboratories through consultancy and sponsored research.

Industry–university interaction

There can be no doubt that industry and technical education are closely connected through a symbiotic relationship. Technical institutions are engaged in educating engineers, while industry employs them on completion of their education. Industry depends largely on engineering institutions for well-educated and well-trained manpower, while technical education derives its objectives and inspiration from industry and its needs. The stimulus and depth of sound academic thinking and accent on problem-solving skills will be of great benefit to industry, while the discipline required in the real industrial world and the stress on decision-making skills will be of immediate benefit to the academic community.

However, especially in the developing countries, engineering education and the people responsible for it are being increasingly criticized for not being in tune with the practice of the profession. The main difficulty appears to involve a mismatch between the education imparted in the technical institutions and the activities of the engineer in industry. It is often pointed out, particularly by industry, that much of engineering education is irrelevant because most engineering teachers are not practising engineers. The charge is magnified when this situation is compared to the use of non-practising physicians as faculty in medical colleges.

When it is realized that technical institutions and industry are so interdependent on each other, with universities engaged in educating engineers, and industry providing employment for (most of) these engineers, it becomes necessary to explore avenues for improved interaction and co-operation between these partners in national development. Additionally, there can be no doubt that we cannot have an active innovative technology without the continuous stimulation provided by research, whether basic or applied. Since the universities are traditionally the place where most research is undertaken, and industry necessarily the place for most technology, what is called for is enhanced interaction between universities and industry. It is quite encouraging to find that on the part of the universities, there is a compulsion to involve the faculty in industrial consultancy and sponsored research; and on the part of industry, mainly through agencies such as the Confederation of Engineering Industry, there is increasing desire for collaboration with universities. The government can play a catalytic role in this interaction through policy initiatives aimed at strengthening the interdependence of industry and university.

The role of sandwich programmes

The sandwich programme or the cooperative system of education, which has found favour in the UK, the USA and Canada, has not yet become popular in India, though a handful of institutions practice it, mostly on an optional basis. The main reasons are the prevalent unemployment situation and insufficient industry–university interaction.

innovation; good, broad-based, scientific background and training in problem-solving; systems approach to the solution of problems; and consideration of social and economic implications of technical solutions.

Brain drain

Brain drain refers to the more or less permanent migration of highly qualified and talented manpower from a less developed country, in which it has been educated by allocating scarce resources, to developed countries. It is estimated that approximately 6000 high-quality personnel migrate from India to developed countries, a significant fraction of this number being engineers, many among them products of IITs.

A recent study has determined that approximately 90% of the migrants are baccalaureate degree holders, and that most of them migrate to North America. The propensity of a graduate to migrate has been found to depend primarily on the place of schooling and the educational background of the parents.

The reasons for migrating can be classified into two complementary sets of factors, described as 'push' and 'pull' factors. The former refer to adverse conditions in India that provoke emigration, the most significant of which are poor career prospects, excessive bureaucracy, emphasis on seniority for promotion, and poor utilization of knowledge. The pull factors refer to the favourable conditions in the developed countries that make immigration attractive, the most significant of which are better academic facilities, a spirit of fun and adventure, better career prospects and financial benefits.

The steps to mitigate brain drain may be classified under three broad categories: information-oriented methods, government-policy-oriented methods and industry-oriented methods.

Performance appraisal system for faculty members

The NPE-1986 has recognized the important role to be played by faculty members of engineering colleges in implementing the various programmes and projects in the areas of technology development and technical education. In addition to the self-evident responsibility to educate and train students, faculty members have to perform other functions, such as academic administration, development of teaching resource materials, industrial consultancy, sponsored research, organization of continuing education programmes, research, curriculum development, extension services to the community, etc.

In order to promote excellence of individuals and institutions, and in order to motivate the faculty members to give of their best, it is necessary to create an ambience within the institutions that promotes the search for excellence, improves their performance and provides opportunities for their development. For this purpose, each institution should devise a dynamic system of planning, implementation, review and feedback, on a regular basis. The appraisal of teacher performance is an important component of this system, in as much as it demands accountability from the teachers.

The NPE stipulates the introduction of an open, participative and data-based system of performance appraisal for faculty members, which would lay down norms of accountability, and a scheme of incentives and rewards for good performance. The AICTE has prepared a detailed document on Performance Appraisal and Development System (**PADS**) after a series of meetings and discussions. The document provides broad guidelines and a framework for introduction of the scheme, along with sample appraisal instruments that provide guidance to each institution for developing its own mechanisms, procedures and appraisal instruments.

The role of professional societies

There are many professional societies in India at the present time, covering a wide spectrum of specializations. Most of them have annual conventions, conferences, journals, etc.; some conduct examinations leading to a qualification that has by and large been accepted as equivalent to a bachelor's degree in engineering. There have been one or two attempts to form a confederation of these societies in order to serve as a potent force capable of providing informed professional advice to the government on relevant policy matters. Another important role played by professional societies in Western countries is the maintenance of academic standards in engineering institutions through accreditation procedures. However, in India, professional societies have not yet addressed themselves to these two tasks; the accreditation proposed in the AICTE Act will be implemented through a board, which will have representation from the professional societies, but will be controlled by the MHRD itself.

Some other curricular issues

Long gestation periods. It is characteristic of the education system that the results of plans take a minimum period of 5 years or more to be realized. This calls for careful forecasting and planning.

Laboratory instruction. Over the years, both the teachers and students have been losing interest in laboratory-based studies. This is also aggravated by the proliferation of computers, and the independence and comfort that the computer environment affords to the student. However, it must be recognized that there is no substitute for laboratory-based instruction. In addition to being a means of verification of theory, laboratory experience puts reality into theory, indicates the limitations of theory in real-life situations, develops familiarity with instruments and equipment, teaches techniques and procedures, and aids the student in creating the motivation to reason and to analyse. It is imperative that its importance is reiterated and steps are taken to revitalize it.

Industrial training. Whether or not the graduate finally ends up in industry, the workplace for engineering and technology is industry, just as the workplace for medicine is the hospital. It is necessary to incorporate a minimum period of industrial internship in the engineering programmes.

Feedback system. In order to ensure effective education processes, it is important to provide a feedback loop, from the employers and also from the alumni. Unless this is systematically practised, it will not be possible to weed out obsolescence and bring in contemporary practices and information.

Distance education. With the setting up of the Indira Gandhi National Open University and its regional centres, this mode of education is making an impact in general education. There are some attempts to try this out in engineering education also. However, it is necessary to study the implications.

CONCLUDING REMARKS

The engineering education programmes in developing countries face special problems arising from ambitious programmes for industrialization without concurrent planning for technical and engineering education. An additional factor that complicates the education programmes is social pressure and demand for higher education.

The main problems facing engineering education in developing countries are as follows:

1. The rush towards higher education overloads the institutions of higher education, particularly those of engineering education.
2. The national plans of education do not normally consider the actual demand for graduate engineers.
3. The educational plans do not normally consider the actual demands for other levels of manpower, such as skilled workers and other technicians needed to support the processes of industrialization.
4. The engineering education plans do not often consider the distribution of specialization in relation to the present and future state of industrialization.
5. The funds allocated for engineering education are often insufficient; this results in very low staff–student ratios, inadequately equipped laboratories, etc.
6. The objectives of scientific and technological research work are often vague and ill-defined; the goal in many cases is mainly to obtain research degrees, which may or may not be connected with national development efforts. Peer recognition internationally is often considered more important than relevance to the solution of down-to-earth problems facing the country.

Acronyms

ABET	Accreditation Board for Engineering and Technology (USA)
AICTE	All India Council for Technical Education
COST	Committee on Science and Technology
EDCIL	Educational Consultants India
IIM	Indian Institute of Management
IISc	Indian Institute of Science
IIT	Indian Institute of Technology
JEE	Joint Entrance Examination
MHRD	Ministry of Human Resources Development
NABTE	National Accreditation Board for Technical Education
NCST	National Committee on Science and Technology
NPE	National Policy on Education (1986)
PADS	Performance Appraisal and Development System
QIP	Quality Improvement Programme
REC	Regional Engineering College
SACC	Scientific Advisory Committee to the Cabinet
SCIP	Special Committee for Implementation of Projects
SEC	State Engineering College
TTTI	Technical Teacher Training Institute
UGC	University Grants Commission

REFERENCES

1. Indian Society for Technical Education *Quality Improvement Programme Brochure and ISTE Handbook* 1990–91. (1990).
2. S. Balaraman, K. S. Hedge and S. Ramani, Goals of basic engineering education in India. *Engineering Education*, 169–175 (November 1978).
3. V. Rao Aiyagiri and P. J. Lavakare, S and T planning—policy formulation in science and technology. *World Science News*, 20th Anniversary, 150–163 (1985).
4. Ministry of Education, Government of India, Challenge to Education—A Policy Perspective. New Delhi (August 1985).
5. Ministry of Human Resource Development, *National Policy on Education* 1986. New Delhi (May 1986).
6. Ministry of Human Resource Development, *Programme of Action*. New Delhi (November 1986).
7. Ministry of Human Resource Development, *IIT Review Committee Report* (1986).
8. ISTE (reproduced), *The AICTE Act*. New Delhi (20 October 1988).
9. R. Natarajan, Engineering education for national development, presentation at the 1990 American Society of Engineering Education Conference, Toronto, Canada (1990).