

Innovative Approaches to Engineering Education – ***AN INDIAN PERSPECTIVE***

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- **Science, Engineering & Technology**
- **India – diversity and opportunity**
- **Engineering education in India**
- **Science & Technology status**
- **Innovative approaches**
- **Concluding remarks**



CAETS Symposium & Annual Meeting ♦ Budapest ♦ June 27-28 2013

Axioms Revisited

- **Knowledge** is an awareness of factual information and evolves through time and stages of learning
- **Learning** means measurable and relatively permanent change in behavior through experience, instruction, or study involving **detection and correction of error**
- **Education** (is) ... imparting or acquisition of knowledge; mental or moral training; cultivation of the mind, feelings and manners. It can either be formal or informal.
- **Science: why?** Curiosity driven irrespective of promise or scope of application (logical pursuance of understanding)
- **Engineering: how?** Skill driven urge to replicate, imitate or master nature and solve problems - designing solutions
- **Technology:** Science + Engineering + Societal factors
- **Innovation:** Value addition through novel thoughts and new techniques resulting discoveries facilitating **improved products, processes, system and life style**

INDIA - A LAND OF DIVERSITY



The highest education is that which does not merely give us information but makes our life in **HARMONY** with all existence
Rabindranath Tagore

INDIA AT A GLANCE – FACTS AND FIGURES

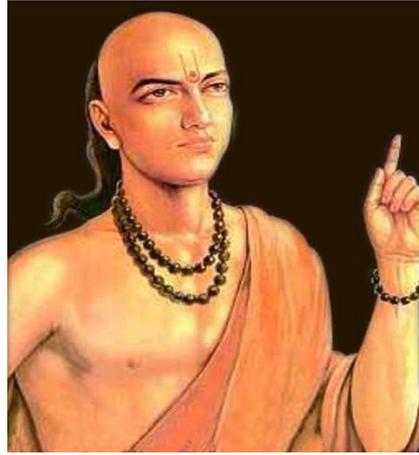
- ❖ Seventh-largest **AREA** (3,287,263 km²), 2.4 % earth's surface
- ❖ Second largest **POPULATION** (>1.22 bn), world's 16.7% population
- ❖ Per capita **income**: Rs. 5,729 per month in 2012-13 (~ \$ 100)
- ❖ Population below poverty line = 29.8%, HDI = 134th (lowest) in **G-20**
- ❖ 10th largest **ECONOMY** by nominal GDP and 4th largest by PPP
- ❖ Life expectancy (65.4years) is close to world average (69.8 years)
- ❖ Population with at least Secondary Education is 26.6% (<<World)
- ❖ Exports: \$299.4 billion (2011) - **19th largest exporter** in the world
- ❖ Imports: 2214.49 INR Billion in February 2013 - **10th largest importer**
- ❖ India is one of the **11 nuclear harnessing** states of the world.
- ❖ Possesses an active **Missile and Satellite launching** program
- ❖ Chandrayaan-1 (unmanned **lunar exploration mission**) 22 Oct 2008
- ❖ 625 bn telephone subscribers, > 2584 million mobile users
- ❖ Indian Railways: Largest employer with ~ 0.1 million km railroad
- ❖ India is the world's **9th largest** civil aviation market and is growing
- ❖ **Average age is 29 with 65% population below 35 years of age**
- ❖ **Education in India is fast changing from traditional to modern**

Education in Ancient India (3000 BC)





Kanad
(600 BC)



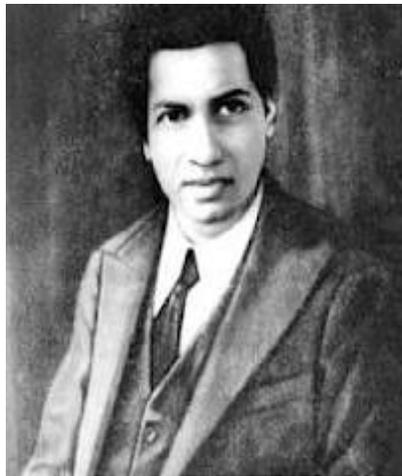
Aryabhata
(476-550 A.D.)



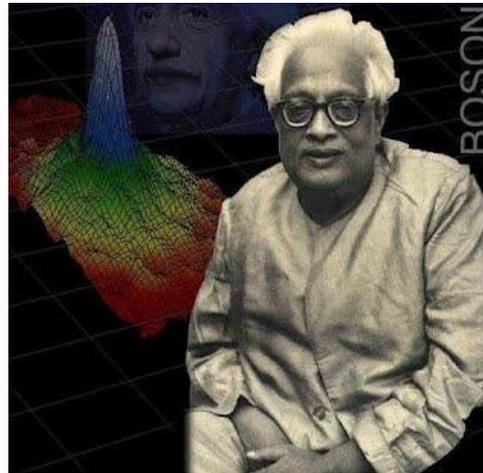
Sir JC Bose
(1858-1937)



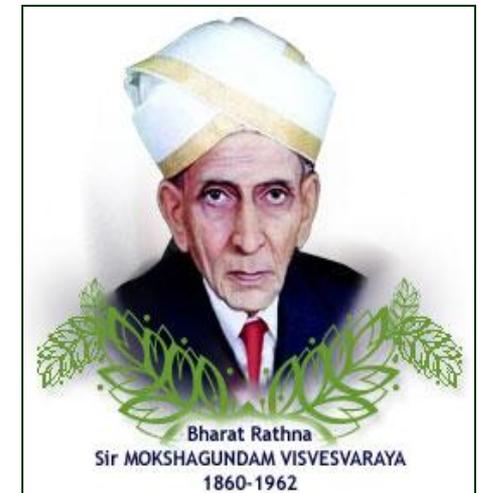
Sir CV Raman
(1888-1970)



S Ramanujan
(1887-1920)

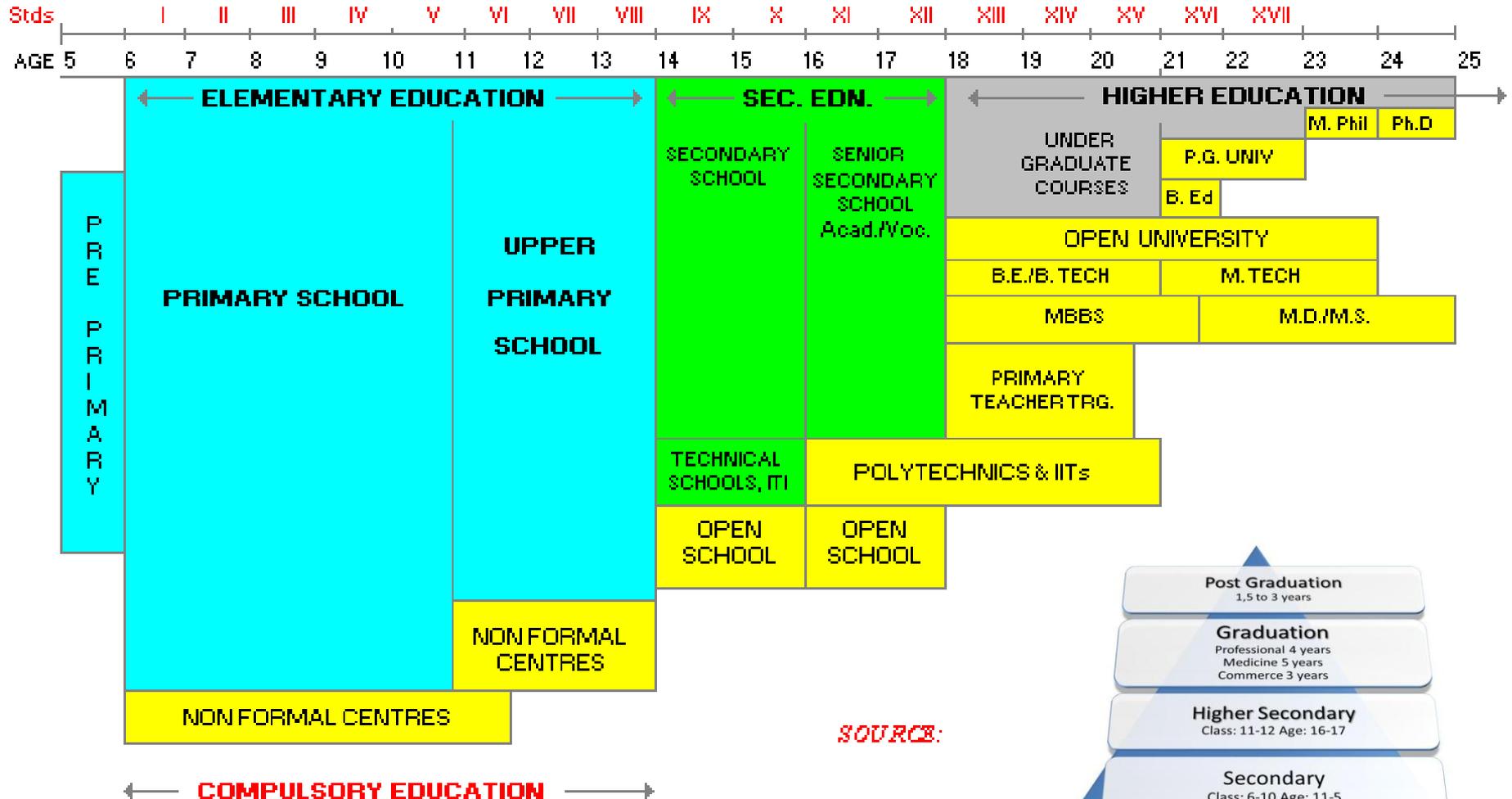


SN Bose
(1894-1974)



M Visvesvaraiyah
(1860-1962)

Stages of Education in India

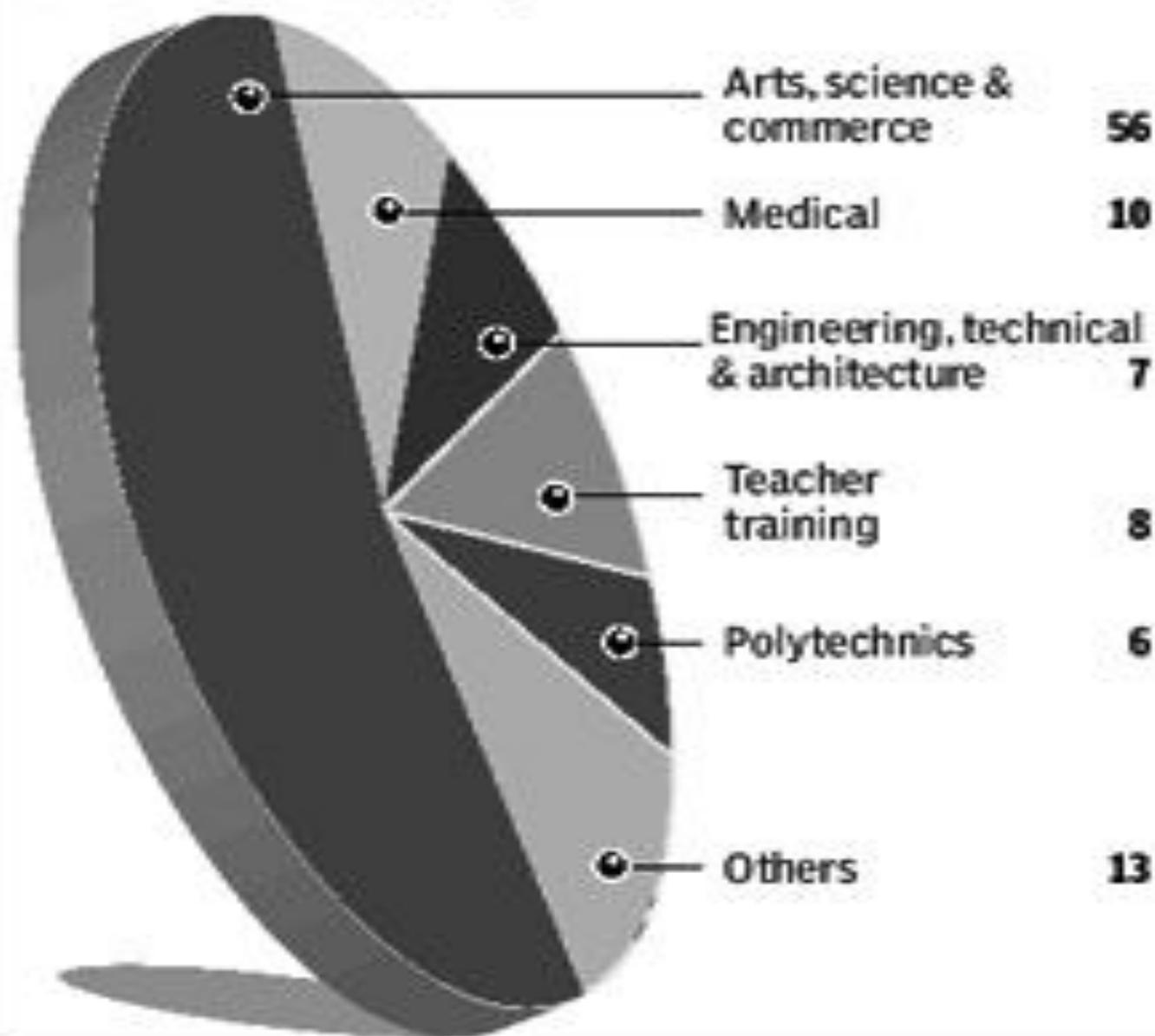


SOURCE:

India Higher Education
indiauniversity.me

India's higher education institutions

Branch-wise shares (in %)

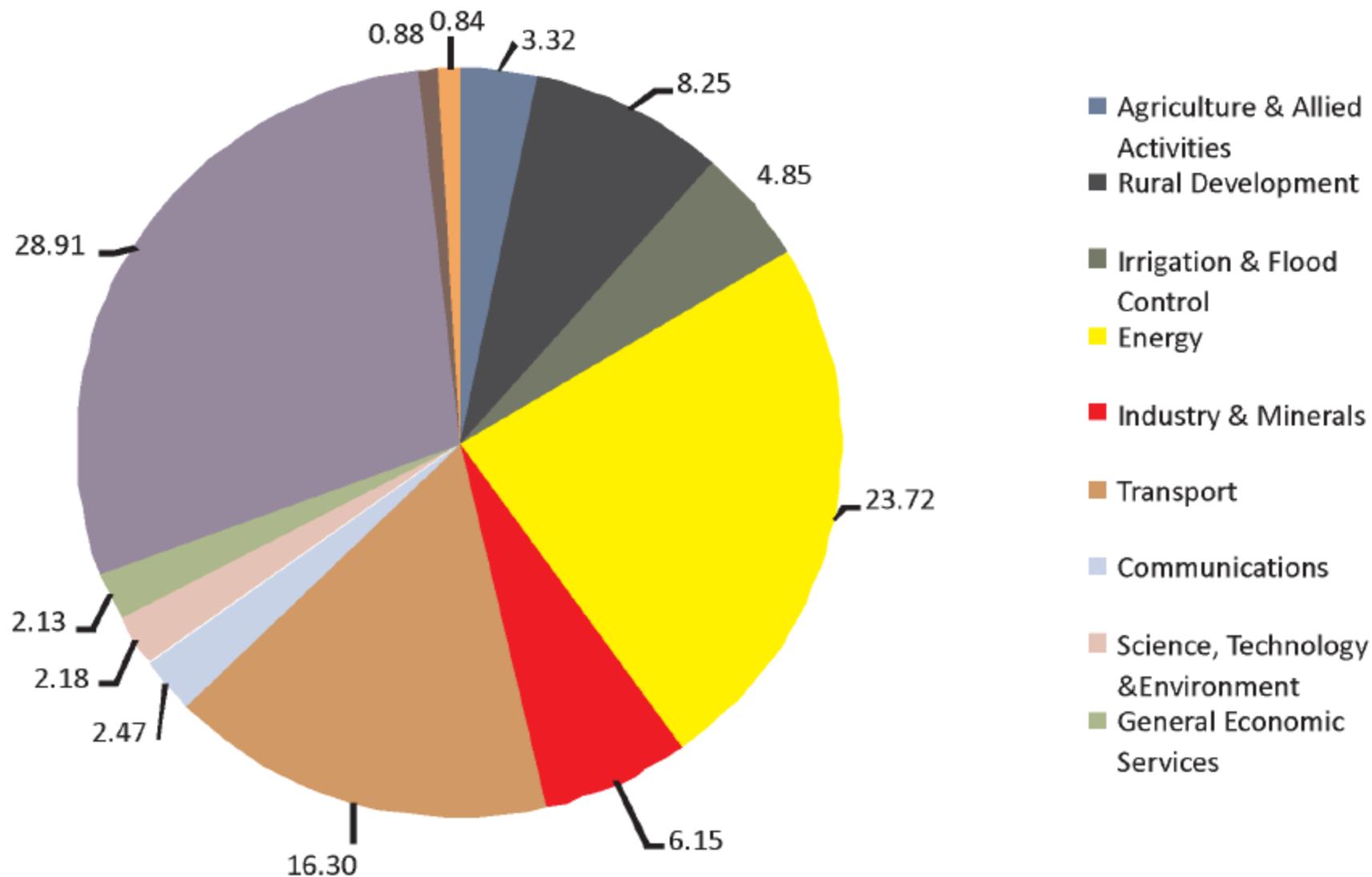


Why engineering education is more attractive in India?

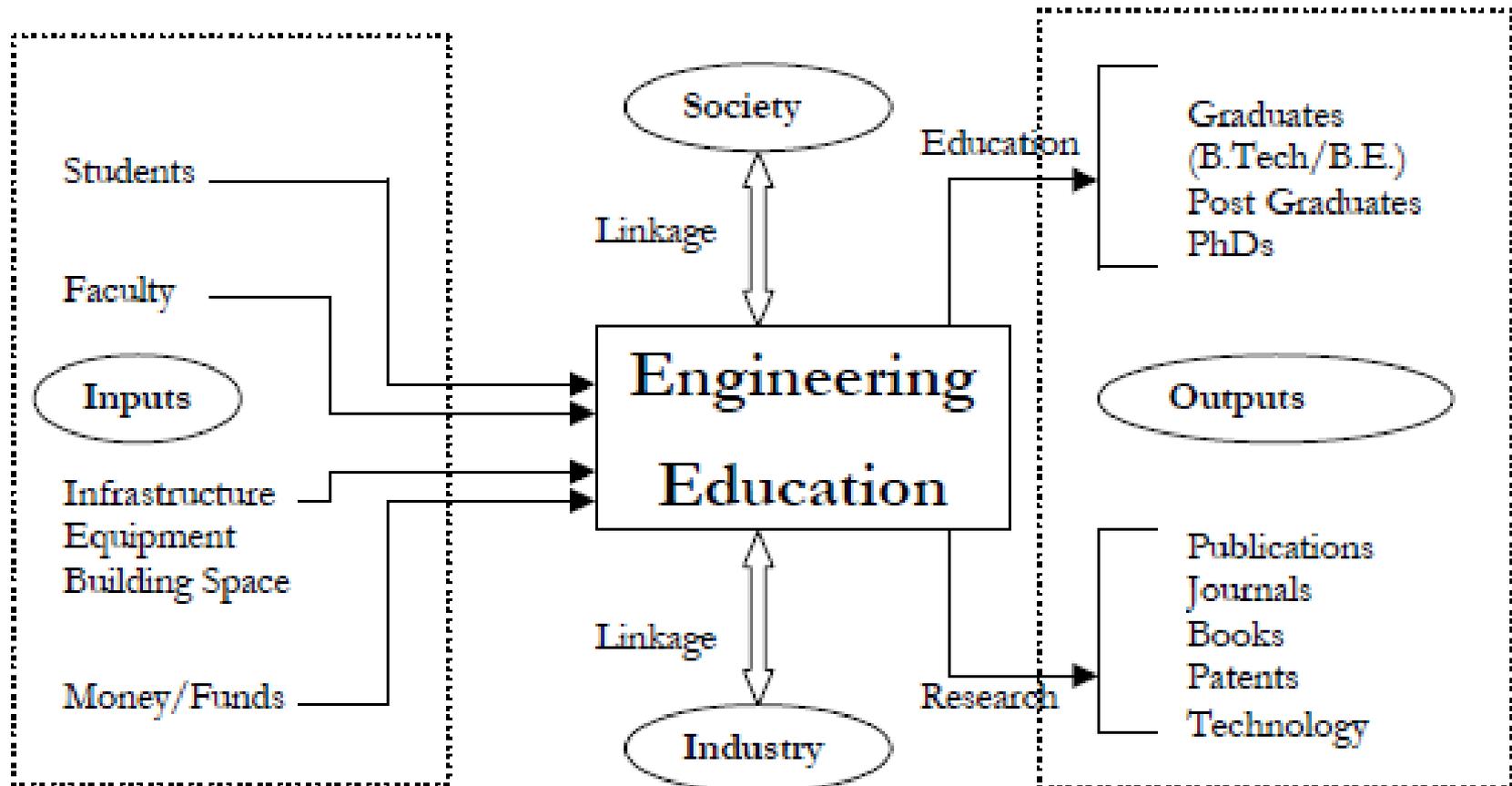
Money, Prestige, Professional training, Job options, Intellectual skill development, Career challenge and opportunity, Entrepreneurship, Creativity, Discovery, Need and relevance to society



Budget Estimates of Annual Plan 2010-11 for Centre, States & UTs



Engineering Education



Schematic of Inputs and Outputs for Engineering Education

Thrust Areas of Research

- **Sustainable Photovoltaics:** Develop next-generation materials, devices, and manufacturing processes tailored to India's needs, environment, and resource availability
- **Multiscale Concentrated Solar Power:** Overcome critical science and engineering challenges for reliable multiscale (including small 25–500 kW) CSP systems
- **Solar Energy Integration:** Identify and assess key technical, economic, environmental, and policy barriers to enable a research agenda for technical readiness in India.



Number of engineering colleges and intake

	1977-78	2008-09
Colleges	562	2,388
Intake	134,894	820,000

Percentage of engineering UG and PG students among university students

Country	UG Engg. students	University students	% Engg. students of total	PG Engg. students	Total PG students	% Engg. PG students of total
India	696,609	11,777,246	6	28,000	872,161	3.4
China	4,376,167	13,334,969	34	302,296	779,408	39

Number of Ph Ds in engineering and technology

Country	Population (billion in 2009)	GDP thousand US\$ (2010)	No. of Ph Ds in engineering and technology	
			1995	2008
USA	0.31	14.1		8,110
China	1.33	5.0	1,659	15,073
India	1.15	1.5	348	1,058

R&D, academic R&D and citations of three countries

	India	South Korea	USA
GDP (in billion US\$)	1,100	970	14,000
R&D as percentage GNP	~ 1	3	2.8
Academic R&D as percentage of total R&D expenditure	4	11.5	20
Citations to all papers relative to national GDP	< 0.02	0.07	0.25
Wealth intensity (PPP-adjusted) per person	2,900	15,600	35,800

R&D expenditure (government and business) and R&D personnel

Country	Year	Amount (US\$ million)	% GDP	Share of expenditure		R&D personnel per million people
				Business	Government	
India	2007	24,439	0.76	33.9	66.1	119
China	2009	154,147	1.7	71.7	23.4	715
Japan	2009	137,908	3.33	75.3	17.7	5,300
South Korea	2008	43,906	3.36	72.9	25.4	3,732
Brazil		21,649	1.08			
USA	2009	401,458	2.88	59.7	31.3	4,628

Relevant Data on Technical Education

- **Enrolment in Universities and Colleges (Regular Stream): 16.975 million**
- **Enrolment in Distance Learning: 3.745 million**
- **Enrolment of Women (Regular Streams): 7.048688 million**
- **Enrolment in Post School Diploma/PG Diploma: 1.856 million**
- **Women in Professional Courses: 23.53 %**
- **Intake in Technical Education: 2.615 million**
- **Institutions in Technical Education: 11809**
- **Number of Universities: 523 +200 (distance teaching mode universities)**
- **Number of Colleges: 33,023 (including 3982 for women)**
- **Faculty members: 0.817 million**
- **Academic Staff Colleges: 66**

(Source: MHRD Annual Report (2011-12) UGC Annual Report)

Higher and Technical Education

Technical Education

- 81 Central Government funded institutions along with State government funded and Self-financing Institutions.

Technical and Science Education

- **Centrally Funded Institutions Number of Institutions - 81**
- Indian Institutes of Technology (IITs) : 16
- Indian Institutes of Management (IIMs) 13
- Indian Institute of Science (IISc.) 1
- Indian Institutes of Science Education and Research (IISERs) 5
- National Institutes of Technology (NITs) 30
- Indian Institutes of Information Technology (IIITs) 4
- National Institutes of Technical Teachers Training and Research (NITTTRs) 4
- Schools of Planning & Architecture (SPA). 3
- Other area/sector institutes of technology 6

- **Apart from technical and scientific Institutions, other centrally funded Institutions are Central Universities (42), Deemed to-be Universities (129), Planning and Consultancy Institutions (2), Institutions of National Importance (30).**

- **Establishment of the National Commission for Higher Education and Research**

Engineering Education in India

Weakness and Problems:

- ❖ **Very small PhD Scholars (~1000-2000/year), Very few post-doctorates**
- ❖ **Poor Academia-Industry interaction, need to revamp engineering education system, faculty-mentoring/assessment/support services**
- ❖ **Need to redefine goals/quality, pursue excellence, introduce sense of competitiveness, and imbibe national relevance**
- ❖ **Failure to identify and satisfy stakeholders**
- ❖ **Downfall in professional ethics and values, and lack of societal relevance and responsibility**
- ❖ **Skill and vision deficit, lack of motivation to change or adapt**
- ❖ **Dearth of well-qualified faculty and difficulty attracting and retaining motivated faculty members in engineering profession**
- ❖ **Lack of autonomy and adequate resource generation**
- ❖ **Lack of discovery based courses that will excite bright students**
- ❖ **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 to overcome from above weaknesses**

Strength of Higher Education Policy

- The growth of higher education in the post-1980 period in India through **private enterprise** has been **demand-driven**. This has been largely in vocational streams and in job oriented courses. However, entrée for foreign universities (**FU Bill**) is still pending in Parliament

Weakness of Higher Education Policy

- In education, growth is largely through **private** initiatives.
- Public funding for higher education is **not enough** for growth
- Poor funding has resulted in the **deterioration of standards** of higher education in the country.
- A **long-term policy** with clear and coherent objectives for higher education in India is needed. The absence of reliable data makes informed decision making even more difficult.

Engineering Education in India

Salient features:

- If a “grand challenge” for engineering education is *“How will we teach and how will our students learn all that is needed to deal with the challenges of today and tomorrow?”* then the issue is not simply a need for more engineering innovations. The need will have a significant impact on student learning and performance (**empowerment**), whether it is through extensive and able implementation of established practices or academic advancements in ideas, methods, or technologies.
- The foremost approach to engineering innovation today is based mostly on faculty intuition originating from personal experiences as students or teachers. Hardly ever are engineering education innovations grounded in confirmed theories and pedagogical practices, and many innovations once implemented, are **not assessed for their effectiveness**.

INAE Initiatives for Engineering Education

- Supporting industry experts to mentor engineering institutions
- INAE-AICTE Industry Chair Professorship, and 2 more Chair Professorships
- Mentoring of engineering students and teachers by FNAEs (summer interns)
- Mentoring scholars for PhD in engineering in strategic R&D laboratories
- Selection of Young Engineers and election of INAE Fellows (FNAE)
- Travel grants for engineering students and scholars for international events
- Holding national conferences and supervising curriculum and policy documents

Diploma Education and Training

- 1,244 polytechnics with an annual intake of 265,000.
- Rate of growth and quality of polytechnics have decreased in recent years.
- 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.
- Polytechnics is primarily concerned with survival tools for the individual and therefore it is important to recognize that they cater to floor level needs of the industry and are sought after by the poorer sections of the society.

National Policy on Education (NPE) (1986 by Rajiv Gandhi)

- **Operation Blackboard (1987–8)**
- **Restructuring and Reorganization of Teacher Education (1987)**
- **Minimum Levels of Learning (1991)**
- **National Program for Nutritional Support to Primary Education (1995)**
- **District Primary Education Program (DPEP) (1993)**
- **Movement to Educate All (2000) - SAA**
- **Fundamental Right to Education (2001)**

Proactive Measures for Enhancing Standard of Technical Education in India – Part A

- **Strengthening Human Capacity for Research:** Innovation in Science Pursuit for Inspired Research (**INSPIRE**) is a flagship scheme of GOI.
- **Strengthening Institutional Capacity for Research:** Fund for Infrastructure Strengthening of S&T (**FIST**), and Promotion of University Research and Scientific Excellence (**PURSE**). 44 universities have been supported under PURSE based on their R&D performance over 10 year.
- **Technology Development and Deployment Mission:** Development of convergent **technology solutions** in addition to technology demonstrations. Focused areas are a) water, b) solar energy, c) affordable health care, d) potash based fertilizer, e) home-land security and f) bamboo-based construction materials.
- **Social Contract of S & T:** DST has supported 66 **Technology Business Incubators** for development of technology based entrepreneurship. Over 28,000 jobs have been created.

Proactive Measures for Enhancing Standard of Technical Education in India – Part B

- **S&T Partnership and Alliances:** 26 State S&T councils supported technology demonstration projects in water management, mangrove protection, waste management, environment management, micro-hydel, and live stock rearing during 2012-13 at multiple locations
- **International S&T Cooperation:** Bilateral S&T cooperation with 40 countries from 83 agreements signed so far has become active. Joint research project based networking of researchers under active bilateral S&T programs of cooperation with substantive programs with 9 countries were reinforced during the year 2012-13.
- **Significant S&T Output from Aided Institutions:** The Department of Science and Technology has been nurturing 16 autonomous research institutions by way of annual Grant-in-Aid. The Department supports also 5 professional bodies and administers two statutory bodies and two sub departments.

Government Measures to Promote Science & Engineering in India

- ❑ **Innovation in Science Pursuit for Inspired Research (INSPIRE):** (a) Scheme for Early Attraction of Talents for Science, (SEATS), (b) Scholarship for Higher Education (SHE) and, (c) Assured Opportunity for Research Careers (AORC).
- ❑ **Kishore Vaigyanik Protsahan Yojana (KVPY)**
- ❑ **Nodal Center for Mathematics and Science Olympiads**
- ❑ **Construction/running of Girls' Hostel for K-10 and K-12 schools**
- ❑ **National Scholarships for school leaving students**
- ❑ **Adult Education/literacy**
- ❑ **Vocational Training Schemes:**
 - **Craftsman Training Scheme (CTS) – Industrial Training Institute (ITI)/Industrial Training Centre (ITC) Training.**
 - **Apprenticeship Training Scheme (ATS).**
 - **Craftsmen Instructor Training Scheme.**
 - **Advance Vocational Training Scheme.**
 - **Women Training Scheme, Research and Staff Training.**
 - **Instructional Material Development for Hi-tech Training**

INDIAN INSTITUTE OF TECHNOLOGY

- **IIT:** Over 60 years old premier institutes for tertiary level teaching/research
- **Image:** Epitome of excellence in teaching, research, students, faculty, facility - all engineering students, researchers, faculty wish to reach/work
- **Reputation:** An international brand name that sells everywhere
- **Highest standard:** Recruitment, career growth, recognition, award (open selection, no promotion – yet conforms to the country's laws and rules)
- **System:** Transparent, no hierarchy, open to scrutiny/criticism, evaluation
- **Self-reliance:** Taught to be independent leader
- **National:** No regional or linguistic bias, truly national institute
- **Contribution:** Students, Knowledge, Tradition, Culture, Infrastructure

Issues for Introspection

1. Why not ranked in TOP 100? Only UG? Output to improve in PhDs
2. Why no papers routinely in the top most journals? Patent to product?
3. How much do our industries need us? Why no major spin off?
4. Is teaching separated from research? JEE /GATE bigger than IIT?
5. What are scholars doing? What are we waiting for? Are we not capable?

Innovative Measures

- A. Project based learning (individual/group),
 - B. Learning through real time problem solving (individual/group),
 - C. Analyze why does the alternative solution fail (explain why age old solutions or models cannot be easily replaced),
 - D. Study the history of material/component evolution and its impact on society (motivation to successful design),
 - E. Group discussion and term paper.
-
- Besides these, supplementary innovative approaches, that can make engineering education more effective and universally appealing:
 - (a) animation and videos,
 - (b) simulation and modeling,
 - (c) reverse engineering, and
 - (d) tinkering to explore new engineering designs and processes.

Implementing Kakodkar Committee Recommendation

- 1. Research Infrastructure:** Significant augmentation required in selected areas. Issues: Space, Modernization, Central facility, Safety/waste disposal code,
- 2. Technology Leadership:** Desirable to assess internal strength, fortify, and then launch (a) Department level, (b) IIT level and (c) National level Mega/Mission projects on a few areas of core strength. Issues: International benchmarking, Roadmap, Networking, Complementarity, Industry partnership
- 3. Industry Interaction:** Essential and welcome; Strategy: Tinkering laboratory, SIDBI entrepreneurship cell, Innovation park at Noida, Short executive training and refresher courses, Individual consultancy/projects, Mega collaboration
- 4. Research Unit by Industry:** Welcome in areas of mutual interest aligned to IIT's core competence and future ambition (e.g. SAMTEL Center)
- 5. Executive MTech:** Agreed in principle, but as MS or MEng with minimum residency period and project under joint supervision
- 6. Resource Augmentation:** Fund raising with active alumni participation and collaboration with national/international agencies
- 7. Faculty Strength:** Continuous recruitment of faculty (100 in 1-2 years), Attractive seed funding and remuneration, Performance based incentives
- 8. Adjunct Appointment:** Will actively pursue from industry, R&D sector, Abroad
- 9. Faculty Appraisal:** Guideline/format being readied though internal exercise
- 10. Innovation & Entrepreneurship:** Several initiatives under progress

Community Engagement and Learning

- **GE3 (Group of environment and energy engineering):** Environment or alternate energy projects (solar tree and solar water heaters)
- **Green Opus:** Bi-annual inter hall festival to motivate students to work towards reducing power consumption and food wastage
- **Green rickshaws:** Green rickshaws operating on electricity run in campus.
- **Plantation drives:** Regular plantation, policy of not cutting trees,
- **Opportunity School:** For children of mess/civil workers up to class 10
- **Opportunity College:** For youth from nearby villages (English and Computers)
- **Community FM channel:** For neighboring community (programs in S&T, plays)

- **Tinkering lab:** Opportunity to tinker with tools, hone skills, build temperament .
- **Planetarium:** A completely student made planetarium (Limca book of Records)
- **Student Wiki:** Voicing, Archiving and Networking the Information (an open wiki)
- **Wall climbing:** An artificial wall for adventure activities and learning
- **Introduction of various art and cultural forms**
- **CDSS (Center for Development of Soft Skills)**



Innovative Education Strategy at IIT Kanpur

- 1. Faculty adviser and mentors for freshers**
- 2. Orientation program for fresh students at UG and PG level**
- 3. Vivekananda Youth Center with soft skill training and societal activities**
- 4. Technical Education Quality Improvement Program – Nodal Center**
- 5. National Program on Distance Education (NPTEL) courses**
- 6. Repository of video lectures of core and elective lectures**
- 7. Higher level question papers, examination and degree (Honors)**
- 8. Double major, Dual degree, Open elective, Minor in Engineering**
- 9. Special courses for reserved category students (affirmative action policy)**
- 10. Joint supervision of doctoral students between academia and industry**
- 11. Tinkering laboratory – licence to make a mistake and learn in the process**
- 12. Job shed and Incubation Center to promote entrepreneurship**
- 13. Societal Mission Projects – water, tannery, sanitation, waste to wealth
(Frugal Innovation Center)**
- 14. International Collaboration – MoU on Student and Faculty exchange**
- 15. Mega Mission Project – multi-party/ multi-disciplinary and multi-organization**
- 16. Executive MS program and Adjunct Faculty position for/from industry**
- 17. Post-doctoral Researcher, Research Engineer/Scientist**
- 18. NIT to IIT link for direct ‘Integrated PhD’ program**
- 19. Center on Society-Engineering or Culture-Technology Interface**
- 20. Industry participation in teaching and research**

CONCLUDING REMARKS

It's not enough that we do our best; sometimes we have to do what's required

Sir Winston Churchill

“I am enough of an artist to draw freely upon my imagination. Imagination is more important than knowledge. Knowledge is limited. Imagination encircles the world.”

— Albert Einstein