Curriculum Innovation for Design Engineers

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Outline

• Need for innovation for India’s tomorrow

• Evolution of engineering

• BTech curriculum for design and innovation

• Conclusions
Services vs Intellectual Property

• Manufacturing and services: earnings proportional to effort
  ➔ linear growth (e.g. Infosys, TCS, Maruti…)

• IP: one time effort for design, earnings thereafter with minimal effort
  ➔ exponential growth possible (e.g. Google, Microsoft…)
Service vs IP

- **IT services @Rs.10 lakhs/person-yr:**
  - 2 lakh programmers/operators = Rs.20,000 cr/yr

- **IP on 2G cellphones @3% royalty:**
  - 200m cellphones/yr = Rs.1,800 cr/yr

- **IP on 4G cellphones @15%:**
  - 200m cellphones/yr = Rs.24,000 cr/yr

Prosperity for all Indians in a short time requires exponential growth

- need ownership of IP
- need engineers who can make India the Design House for the world
Evolution of Engineering

The Middle Ages to early 20th century, design as an art:

• Leonardo da Vinci
  - Italian polymath: artist, sculptor, painter, engineer, inventor…

• Robert Fulton
  - American artist, mechanical inventions as a hobby
  - First commercially successful steamboat

• Samuel Morse
  - painter until age 34
  - turned to long distance communication when wife died
  - co-inventor of telegraph and Morse code
Engineering Education

• Engineer as an artisan
• Apprenticeship to acquire skills and experience of a master
• Development of handbooks with numerical tables, designs, rules of thumb
Engineering and World War II

- Pre-WW-II, lip-service to science to give respectability
- During WW-II, true science base grew
  - Development of radar, sonar, radio
  - Encryption and code-breaking
  - Operations research for logistics
  - ...
Education Post WW-II

• Strong push towards science-based engineering curriculum, especially in US
• Driven by MIT, Stanford and other research Universities
• Spurred by generous funding from US Government (Military and NSF)
• Maths-based (analytic) courses gained higher status than design-based (synthesis) courses
• Dependence on computer simulation/design without understanding its limitations
• Japan, Germany and Netherlands retained strong emphasis on practice
**Successes**

Space Shuttle

**Failures**

Challenger Space Shuttle explosion: failure of an O-ring seal
Tacoma Narrows Bridge: collapsed due to a modest 70 kmph crosswind

http://www.enm.bris.ac.uk/anm/tacoma/tacoma.html
Technology Ups and Downs

• **Cause of these spectacular failures:** design flaws that could easily have been avoided

• **Successful design requires a judicious mix of** science, computation and hands-on experience
The Pendulum Swings Back

- Shift back to including design in engineering education
- Conceive-design-implement-operate (CDIO) initiative in UG education, by MIT
- Incubation of technology product companies by IIT Madras since 1992
  - >200 startups by IITM faculty, students
  - students work on industry projects
- Design & Innovation curriculum in IIT Mandi BTech
Innovation at IIT Mandi

Teaching and research culture to foster Design & Innovation
Inter-disciplinary culture in teaching & research

Unique Design-oriented B.Tech. curriculum

Practicum: Practice before theory
- Self-motivated students learn on their own, become leaders
- Others appreciate theory when it is taught later

Design & Innovation Stream in B.Tech.
- Inter-disciplinary teams with assigned partners
- Systematic, documented working including
  - Problem definition
  - Demo of working product/prototype
  - Weekly reviews with minutes of meetings
Year 1: Reverse engineering

- Random, inter-disciplinary teams
- Study existing products, eg. Fan, toaster, ...
- Disassemble and document its design
- Reassemble
Year 2: Design practicum

- Practice before theory
- Design and build prototype product for real-world problem
- Random, inter-disciplinary teams

Projects by 2nd B.Tech. students

- Temperature-controlled magnetic liquid stirrer for research labs
- Voice-controlled wheelchair for quadriplegics
- Cellphone charger driven by leg while walking
- Drip irrigation system
Year 2: Design practicum

Low-cost 3D printer, gas-leak detector, smart board, clothes drier, oil-spill remover, ...
Yr 3: Socio-Technical Practicum

3rd BTech Practicum
Projects on social impact of technology, market research
15-25 UG students from WPI, US resident in Kamand for 3 months/year

- Direct solar lighting for village houses
- Quality of milk
- Irrigation in the Himalayas
- Hill farm mechanisation
- Womens education
- …
Water Bottle Solar Light
Year 4: Major technical project

- Capstone of the 4-year programme
- Major technical contribution in the discipline
- Individual or self-chosen team
Industry Interactions

• Industry engineers as guest/adjunct faculty
• Industry-sponsored research projects
  Applied product-oriented R&D with deliverables
  Flexible IPR agreements to suit the needs
• Entrepreneurship
  Virtual student companies, IIT as the customer
Outcomes at IIT Mandi

- **IIT Mandi web-site** designed by 1\textsuperscript{st} B.Tech. students, run by them from 2010-2015
- **Online Faculty Application** portal designed and run by 2\textsuperscript{nd} B.Tech. students, used for 6 years
  - Used by some other institutions
- **Competitive successes**
  - Pradeep Seervi, 1\textsuperscript{st} in GATE(EE) 2015, Aather Khan 2\textsuperscript{nd} in Civil Services in 2015, Nitesh Kumar, Gold in Int’l Parabadminton
- **Placements**
  - Microsoft, Amazon, Infosys, Nucleus Software, Samsung, DRDO, HPCL, Tata Motors, …
  - Universities: CMU, Toronto, Penn State, Georgia Tech, IITs, TU-Munich, …
- **Start-ups**
Conclusions

- Prosperity for all Indians requires design by Indian engineers
- Design is an art, acquired by teaching+learning combo
- We have taken the first steps, results promising

India’s need

Pasteur’s Quadrant

Applications

New knowledge

Pure basic research (Bohr)

Use-inspired basic research (Pasteur)

Pure applied research (Edison)


Charles Vest, *Pursuing the Endless Frontier*, 2004


http://www.iitmandi.ac.in

http://www.tenet.res.in

http://www.cdio.org