Indian Institute of Technology Mandi

Scaling the Heights

Curriculum Innovations for Design Engineers

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20 Jan 2023

Outline

- Need for innovation for India's tomorrow
- Evolution of engineering
- BTech curriculum for design and innovation
- Conclusions

Spiderman outfit
2nd BTech project
IIT Mandi

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, Facebook, …)

Service vs IP

- IT services @Rs.30 lakhs/person-yr:
  - 2 lakh programmers/operators = Rs 60,000 cr/yr
- IP on 4G cellphones @15%:
  - 300m cellphones/yr = Rs.45,000 cr/yr

IP created by a few 100 engineers

- Prosperity for all Indians in a short time requires exponential growth

➔need ownership of IP

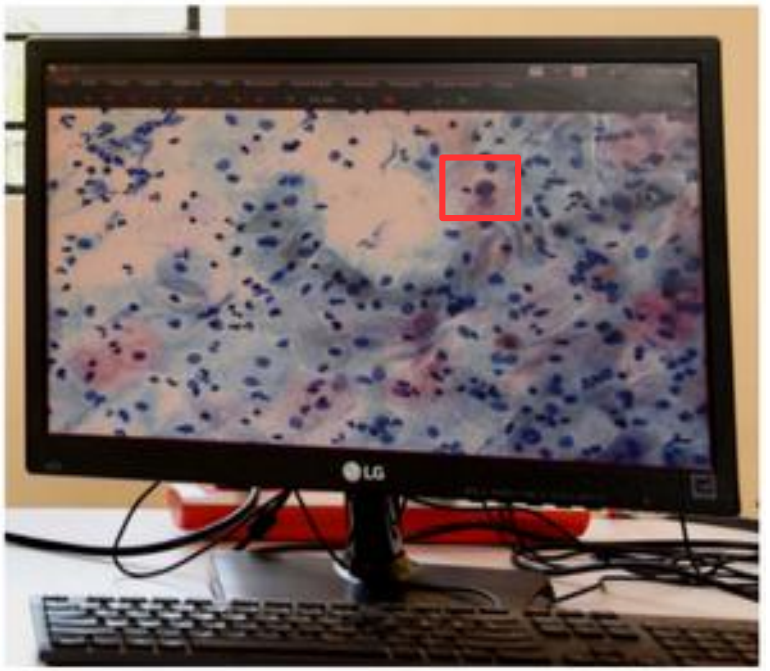
➔need engineers who can make India the Design House for India and the world

MANAS, IIT Mandi

Screening for cervical cancer in villages

3 years R&D with KIDWAI Memorial Institute of Oncology, PGI Chandigarh, Aindra Pvt. Ltd, Bangalore

Aindra product based on IIT Mandi algorithms



https://manas.iitmandi.ac.in/

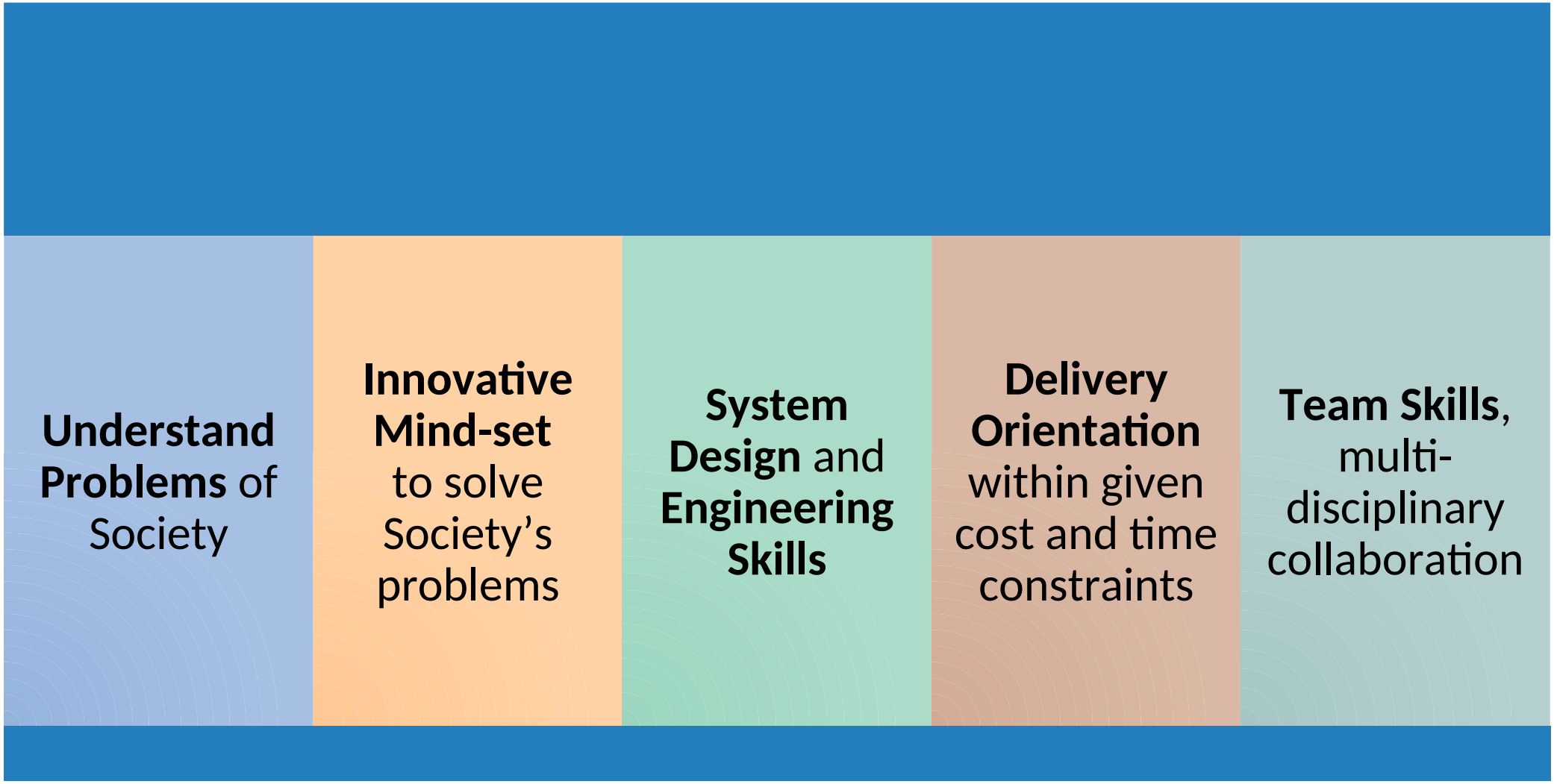
Process for Product in Market

- Conceive – market need, product idea
  - Need – industry, domain experts
  - Ideas – academia, industry
- Design – better than competitors
  - Academia, industry
- Implement – manufacturable, maintainable, recyclable
  - Industry, academia
- Operate – install, repair, upgrade, recycle
  - Industry

http://www.cdio.org/
started by MIT ~2000

Most students learn/experience CDIO only on the job after graduation

Skills of a Design Engineer



Mostly not learnt in the traditional engineering curriculum

Early Engineering

(C) Benh LIEU SONG
https://en.wikipedia.org/wiki/File:Pont_du_Gard_BLS.jpg

Concrete:

Greece 1,400-1,200 BC

Rome 300 BC – 476 AD

- Pont du Gard aqueduct: 2,000 years old

Metallurgy:

The Iron Pillar, Delhi, c. 375–415 AD

- Rust-resistant wrought iron

https://commons.wikimedia.org/wiki/File:Inscription_on_Iron_Pillar,_Delhi.jpg

Engineering without BTech!

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
  - Spurred by generous funding from US Government (Military and NSF)
  - Led by MIT, Stanford and other research Universities
- 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
- IITs largely copied US model
  - IIT Madras inherited the Germany practice-orientation

Vannevar Bush, *Science – The Endless Frontier, 1945*

Successes *Failures*

Space Shuttle

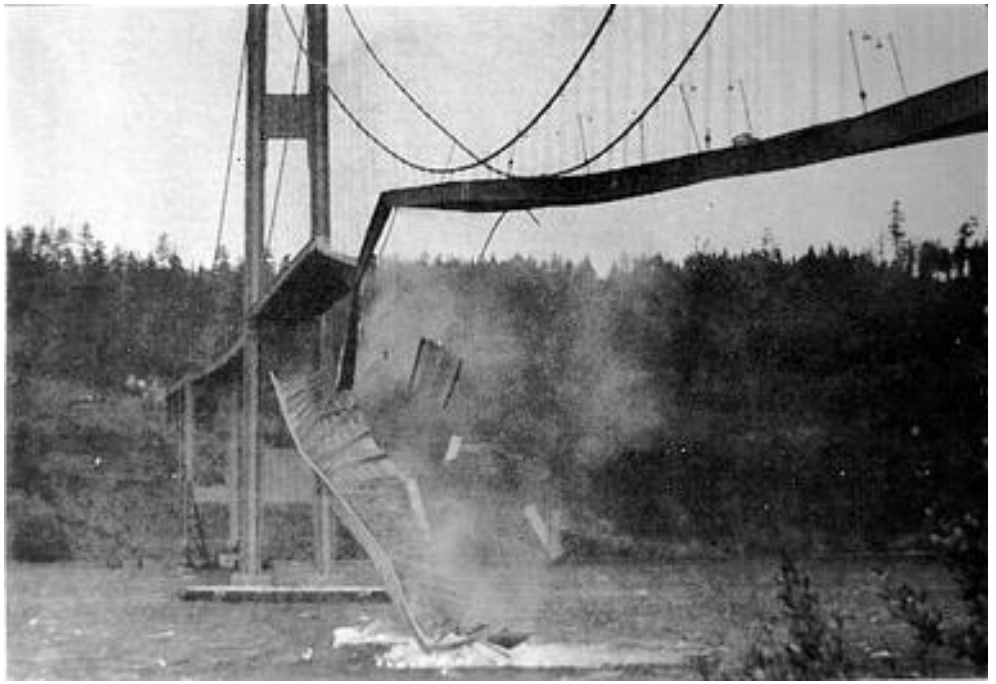
Challenger Space Shuttle explosion:
failure of an O-ring seal

Successes

Golden Gate Bridge:
Designed 1917, opened 1937
Longest and tallest suspension bridge (main span 1,280 m, height 227 m).

Failures

Tacoma Narrows Bridge:
Opened Jul 1940, collapsed Nov 1940 due to 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, technology 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 since 2012

Innovation at IIT Mandi

Teaching and research culture to foster Design & Innovation

Innovation at IIT Mandi

Interdisciplinary culture in teaching & research

Unique Design-oriented B.Tech. curriculum

Practicum: Practice before theory

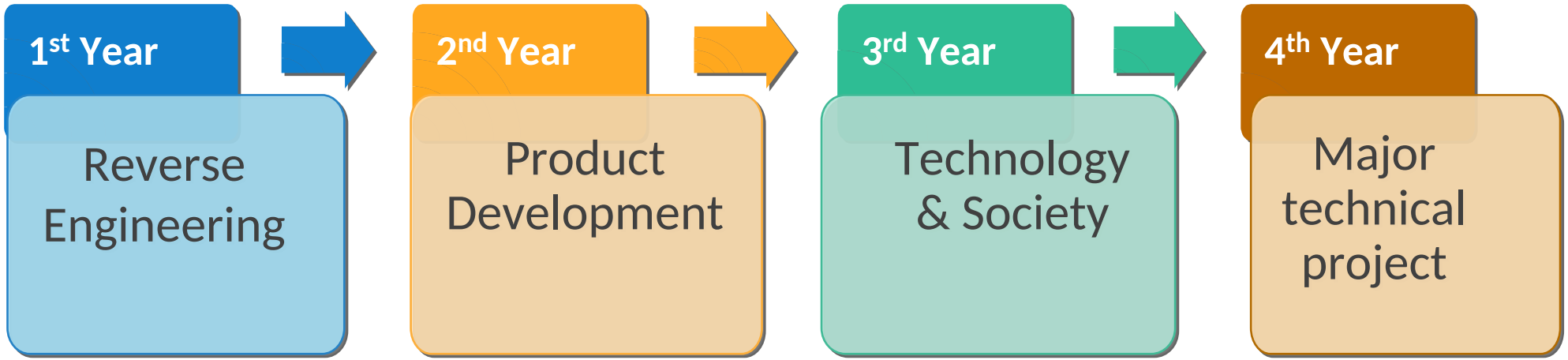
Self-motivated students learn on their own, become leaders

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

IIT Mandi Design-oriented BTech curriculum, since 2012



- Inter-disciplinary academic culture
- Real-world team projects from Year 1 to 4
- Students develop practical devices that serve society's needs

- Ingredients:
  - Learn-by-doing
  - Teamwork
  - Driven by needs of society
  - Strong humanities component

Innovation Stream in B.Tech.

Year 1: Reverse engineering

- Random, inter-disciplinary teams
- Study existing products eg. fan, toaster, …
- Disassemble and document its design
- Reassemble and improve

Year 2: Design practicum

- Practice before theory
- Identify a real-world problem
- Design and build prototype product
- Demo in Open House
- Use COTS, budget Rs. 25K
- Random, inter-disciplinary teams

Projects by 2nd B.Tech. students

- Temperature-controlled magnetic liquid stirrer for research labs
- Voice-controlled wheelchair for quadraplegics
- Cellphone charger driven by leg while walking
- Drip irrigation system →

Innovation by 1st & 2nd BTech (IIT Mandi)

Students design and build useful products in 1st & 2nd year

- Agriculture Tech
- Urban infra
- Home/Office Automation
- Personal Devices
- Personal Health
- Electric Vehicles
- …

Seed Planter

Hexapod Robot

Smart Cane

Low cost 3D Printer

Automated cooker

Automated Floor Cleaner

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
- Postal system in villages
- Womens education
- …

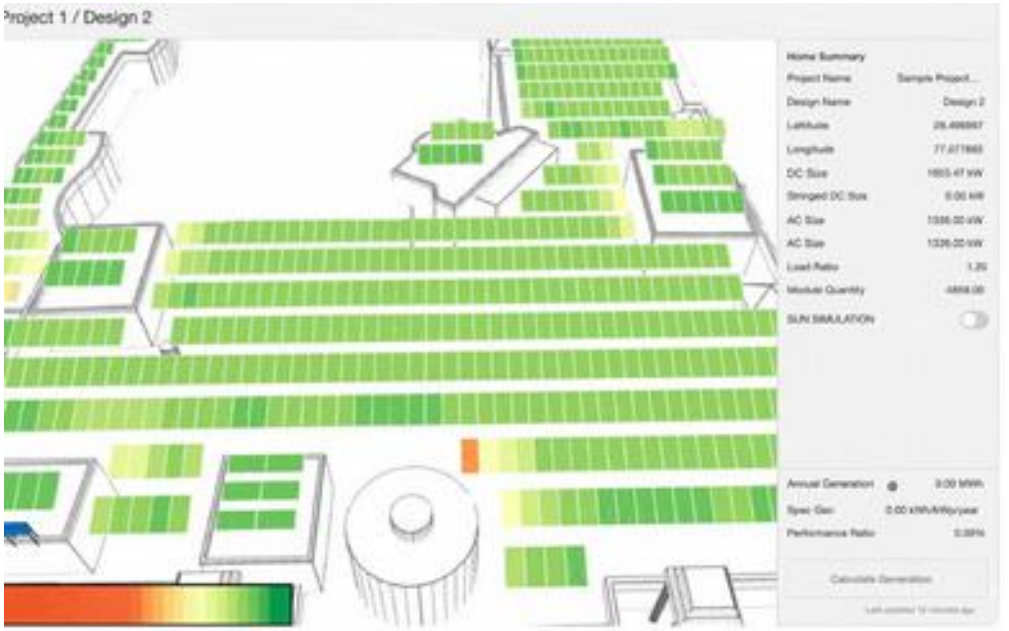
Year 4: Major technical project

Year 4: Major technical project

Capstone of the 4-year programme

Major technical contribution in the discipline

Individual or self-chosen team



Rooftop solar installation planner
Siddharth, Ankush, Mukul

Outcomes at IIT Mandi

- IIT Mandi web-site designed by 1st B.Tech. students, run by them from 2010-2015
- Online Faculty Application portal designed and run by 2nd B.Tech. students, used for 6 years
  - Used by some other institutions
- Placements
  - Microsoft, Amazon, Infosys, Nucleus Software, Samsung, DRDO, HPCL, Tata Motors, …
  - Universities: CMU, Toronto, Penn State, Georgia Tech, IITs, TU-Munich, …
- Start-ups
  - IITians Tech (2014), The Solar Labs (2017), Kriger Campus (2018), …
- Competitive successes
  - Pradeep Seervi, 1st in GATE(EE) 2015,
    Aather Khan 2nd in Civil Services 2015,
    Nitesh Kumar, Gold in Int'l Parabadminton

LEAP – IIT-style PBL for colleges

IIT-style project-based learning for engineering colleges

- Based on experiences at IIT Mandi and IIT Madras
- By IITM IC, funded by Maker Bhavan Foundation

Executed through colleges

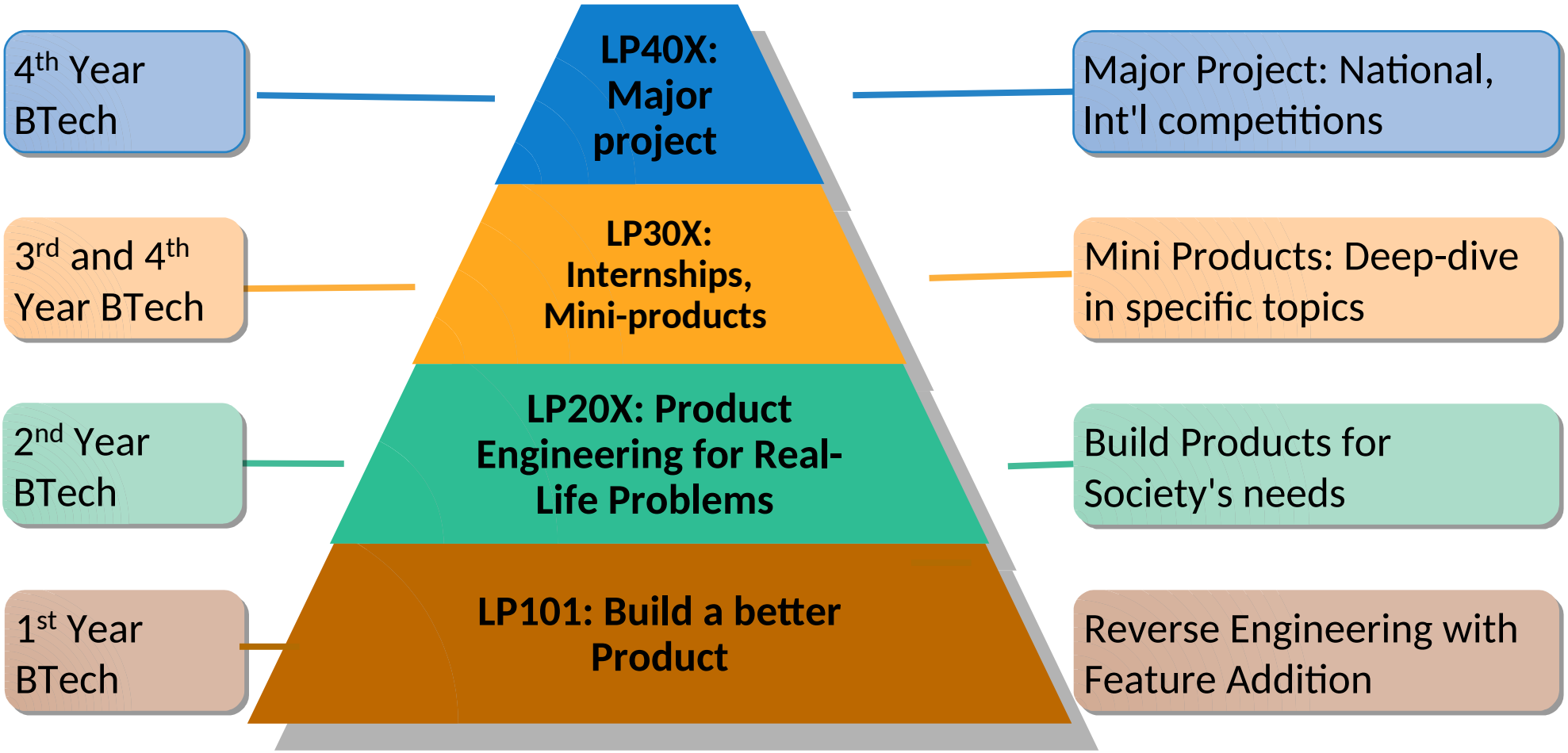
- Faculty trained in the LEAP methodology
- Students teams mentored by college faculty
- Aided by experts from IITs and industry

From 1st year onwards

Industry-oriented skills and networking for students and faculty

https://www.leap.respark.iitm.ac.in/

LEAP: IIT-style PBL for Engineering Colleges



A project in the IIT Madras Incubation Cell
Funded by the Maker Bhavan Foundation, USA

LEAP progress

https://www.leap.respark.iitm.ac.in/

- Since Oct '21
- 110 students completed LP201 in GCE (Tirunelveli), PSVPEC (Chennai), GEC (Idukki)
- 250+ students ongoing in 9 colleges in LP101/LP201

Faculty training
GEC, Idukki

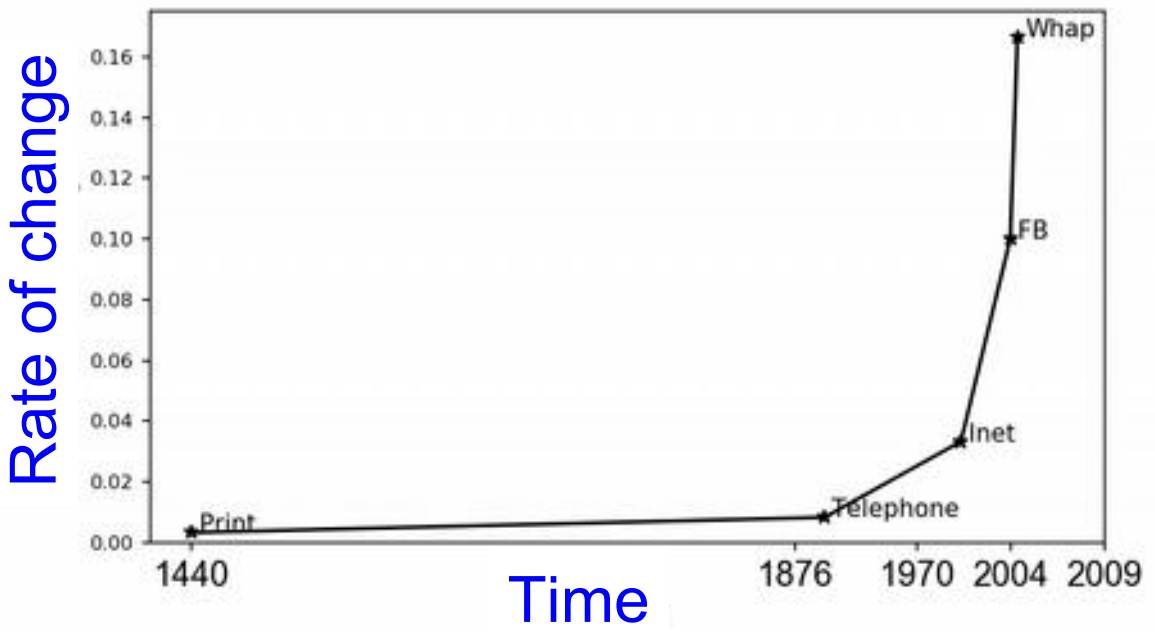
A/C bike helmet

Headlight
dimmer

Conclusions

- India needs innovative design by Indian engineers
- Design an art, acquired by classroom + hands-on learning
- Project-based learning achieves CDIO capabilities
- Inter-disciplinarity is a must for future engineers

- Future of increasing rate of change
- Students need solid foundation + agility to learn on demand



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