ENGINEERING EDUCATION FOR 21ST CENTURY

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Outline

- Introduction
- What is Engineering?
- Some key issues in education
- Instructional objectives
- MOCC – Massive Open On-line Courses
- Vision for 21^{st} century
- Concept of GLOCAL Engineering
- Closing Remarks

Backdrop

- Personal education: International and Inter-disciplinary
- Chemical Engineering as main discipline but worked in aerodynamics, mechanical, metallurgical, mining ,agricultural and food engineering areas internationally
- Worked with over 300 colleagues (coauthors!) in 40 countries; published in several languages as well

More about speaker

- Taught engineering subjects in 4 countries to undergraduate and postgraduates
- Consulted for many companies in R&D and operations and held workshops for industry
- Advised over 60 PhDs and some 40 postdocs and Visiting Researchers from 20 countries
- To sum: worked globally with multi-cultural, multi-lingual teams in multi-disciplinary areas.
- Ideas presented are my own-references given as appropriate)- based on personal observations and philosophy

What Engineers Do?

- Definition from Australian on Learning and Teaching Council (2008)
- “*Engineers conceptualize, create and maintain physical and information-based products, processing systems and assets that satisfy human and economic needs, and have minimal impact on environment and humans*”
- Engineering is critical to national economy: business, government, security, education, health, transport, energy, environment – in short “all aspects of nation-building”
- Engineering is central to innovation and societal development
- Must attract high quality talent to excel !

Canadian Council of Professional Engineers' Criteria

(Ref: Accreditation and Criteria Procedures, 2003, CPPE Section 2.2.7)

- ***"Each programme <u>must</u> ensure that students are made aware of the role and responsibilities of the professional engineer in society. Appropriate exposure to <u>ethics</u>, <u>equity</u>, <u>public</u> and <u>worker safety</u> and <u>health</u> considerations and concepts of <u>sustainable development</u> and <u>environmental</u> <u>stewardship</u> <u>must</u> <u>be</u> integral component of the engineering curriculum***

Above statement is globally relevant for advanced as well as emerging economies. Curriculum must meet these criteria for graduates to be allowed to practice as ENGINEERS!

Academics do not decide these legal requirements.

Some Critical Issues in Engineering Education

- Curricula and Courses
  - Balance fundamentals and applications
  - Integrate material from different courses
  - Include analysis and synthesis
  - Accreditation of programs (e.g. ABET in USA; Washington Accord etc) is important to ensure quality
- Note: Fundamental part is time-invariant; applications are dynamic/transient. These keep the program current and relevant

Some Critical Issues (cont'd)

- Teaching Methods-improve pedagogy
- Teaching-centered vs student-centered teaching
- Individual vs Group learning
- Directed vs Self-directed learning
- Problem-based learning; Case studies
- Innovative learning/teaching; depends on subject/discipline/teacher/Institution/Culture
- Lecture vs Lab instruction – balance needed
- Faculty- should be excellent role models/coaches/mentors
- Professional engineers to teach? Required in Canada
- Industry exposure needed by faculty/students
- Global exposure a major asset- age of Globalization!

- Many more issues to be tackled at different levels

Instructional Objectives – A Primer

Reference: Bloom et al. Taxonomy of Educational Objectives; Addison-Wesley, N.Y., 1984

Objectives of Education are to develop following key skill sets in students

- Lower level skills
  - Knowledge – memorized information
  - Comprehension – explain concepts
  - Application – direct solutions to problems

- Higher level skills
  - Analysis – complex problems, process models simulations
  - Synthesis – design of experiments, equipment, processes/products, etc
  - Evaluation – selection between alternatives, optimization, environmental impact, risk assessment, ethics, etc.

Typically 70-80% of problems assigned in most curricula focus on Level 3 skills (or lower). New ABET requires skills 4-6 to be developed

On Teaching and Learning

- Current focus is on enhancement of teaching using new technology- faster assess to often non-refereed raw excessive data
- Data must be processed to convert it into useful and reliable knowledge- critical assessment and thinking skills are needed
- Fast delivery of knowledge does not translate into rapid assimilation of the same by students
- Transfer of knowledge from teacher to student is a “rate process” where the Flux of Knowledge transferred is dependent on “resistances “ to such transfer (ASM MODEL?)

Teaching &Learning as Rate Processes- ASM Model

- Teaching side resistance can be reduced by excellent teaching with best available tools and methodologies
- Learning side resistance depends on student ability
- A third resistance exists due to inherent complexity of subject or degree of motivation/interest of the receiver
- Net Flux of knowledge transfer, for a given teacher/student/subject system depends on all three resistances which act in series.

Key Components of Good Engineering Education

- Knowledge – well known; dynamic rather than static
- Skills –problem-solving, problem formulation skills , critical thinking, creative thinking; interpersonal and teamwork skills; communication skills; self-assessment and change management skills, etc.
- Learning skills – dependent to independent to interdependent to lifelong learning. VERY IMPORTANT!
- Problem-solving under constraints of time, cost and sustainability
- Problem-posing-even more important skill – going from academic to real-world
- Ethics, impact on society and sustainability (Life Cycle Assessment etc.) – increasingly important issues
- Management of change from passive to active to pro-active learning
- Most current programs meet above set only partially

Vision for 21st Century

- Currently engineering education system is same as it was 50+ years ago – especially mode of delivery
- Some technology – push enhancements are naturally included e.g. manual computations to slide rules to mechanical calculators to electronic calculators to ever more powerful computers etc.
- Challenges: Proliferation of information, e.g. 6000+ scientific articles appear each day!
- Multi-disciplinarity; sustainability, social responsibility; speed of change etc pose new challenges- previously ignored
- Challenges bring opportunities for those prepared to tackle them!

Engineers for Future

Ref: Australian Learning and Teaching Council, 2008

Recommendations:

- Raise public perception of engineering- not entirely an academic issue
- Refine definition of engineering occupations and graduate qualification standards
- Implement "Best Practice" education- better yet "better practices"
- Enhance resources for engineering education
- Engage with industry/ government agencies
- Shortages can be addressed by retraining people from other backgrounds. Where surpluses exist ,plan supply-demand balance well to encourage talent to flow to engineering- a difficult and complex profession !

Recommendations (cont'd)

- All recommendations need extra resources; close match between supply and demand- as practiced by medical dental, legal professions
- Today's engineers need to know more - extra time needed to graduate but the opportunity cost is too high for stakeholders-hence lifelong learning is critical
- Future engineering will be more complex; demanding higher talent base
- Competition with other professions is severe
- To sum: Academics cannot implement all recommendations- government, business and industry must participate in the effort as the nation as a whole is the real beneficiary!

A few general observations

- Enhancing engineering education is a collective effort- even international effort
- Utilize global experience but do not “copy” other models from other geographic, cultural locations- they may not work!
- Diversity in curricula is an advantage- all programs in a nation need not be the same
- Consider local needs, environment and conditions to design optimal engineering programs

General observations

- International exposure of faculty and students is necessary in today's world
- Ability to work internationally in multi-disciplinary, multi-cultural teams is now a necessity- not a choice
- Exchange programs, joint degrees etc is a good option
- Research strengthens teaching and generally makes it current; research-intensive institutions tend to have stronger teaching programs due to better resources
- Lowering costs is a key universal concern globally

MOOC –Massive Open On-line Courses

- Term due to D. Cornier of Univ. of Prince Edward Island, Canada (2008)
- First MOOC taught by S. Downes of NRC, Canada and G. Siemens of Athabasca University, Canada
- Hugely successful model to deliver high quality courses FREE to millions around the world
- Many thousands can take courses free over internet from major universities like Stanford, MIT, Univ. California, etc. Most major universities are participating
- Stanford University has had over 60 million course downloads through iTunesU

MOOC – (cont'd)

- 60% of downloads from 154 countries outside USA; Billions of downloads on iTunes alone
- Very high cost of education is driving MOOC
- Some colleges/universities may give credit for MOOC to reduce residence time on campus
- High motivation and self-learning skills needed for MOOC to succeed
- Overall a good way to lower cost of delivering education where costs have soared at rates much higher than local inflation rates.

Global or Glocal Engineering?

- What is "GLOCAL" engineering?
- Combine "global" aspects with "local"
- Think Global; Act Local
- Local needs, challenges, opportunities vary widely- a program good for one location may not be optimal elsewhere
- Fundamental curriculum could be same globally; application/discipline content should be designed to meet local needs

Global or Glocal Engineering? (cont'd)

- Half-life of engineering programs is short :6-10 years! Need for self-learning and life-long learning is greater than ever
- International exchanges / joint degree programs are valuable to expose students to "global" aspects of culture
- Use of internet to lower costs for teaching and learning without geographic limitations is already being practiced
- Creative innovation is needed at all levels to make Engineering Education for the 21st Century truly beneficial for all stakeholders!

National Engineering Academy Report – – Key Findings (2013)

- Enhance student interest in science and engineering
- Increase visibility of science/engineering to society
- Importance of engineering to policy/ business/law
- Enhance student interest in entrepreneurship – seeking vs creating employment
- Promote collaboration between engineering and science, business, social sciences and humanities
- Distinction between science and engineering is “fuzzy” and highly interdependent. New tools, sensors, instruments, devices for physical, physiological or biological sciences are made by engineers for science to progress

Closing Remarks

- New teaching/learning paradigms needed for 21st century engineering curricula
- Key words: interdisciplinary, international, sustainable, ethical, etc
- Critical sets needed: ability to synthesize, work across disciplines, teamwork, life-long learning, critical thinking, manage rapid change, communication skills, intercultural awareness
- Enhanced teaching/learning/assessment skills
- Think “Global” but act “Local”
- To sum: Future Engineering Education will need to be “Glocal”!