Innovation, the Engineering Profession and Engineering Education

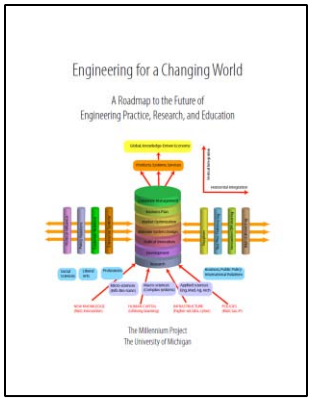
McMaster University
26th Annual J.W. Hodgins Memorial Lecture

Gilles G. Patry
University of Ottawa
October 22, 2009

Outline

- Introduction
- The Canadian Innovation Challenge
- Leadership in the Engineering Profession
- Leadership in Engineering Education
- Conclusions

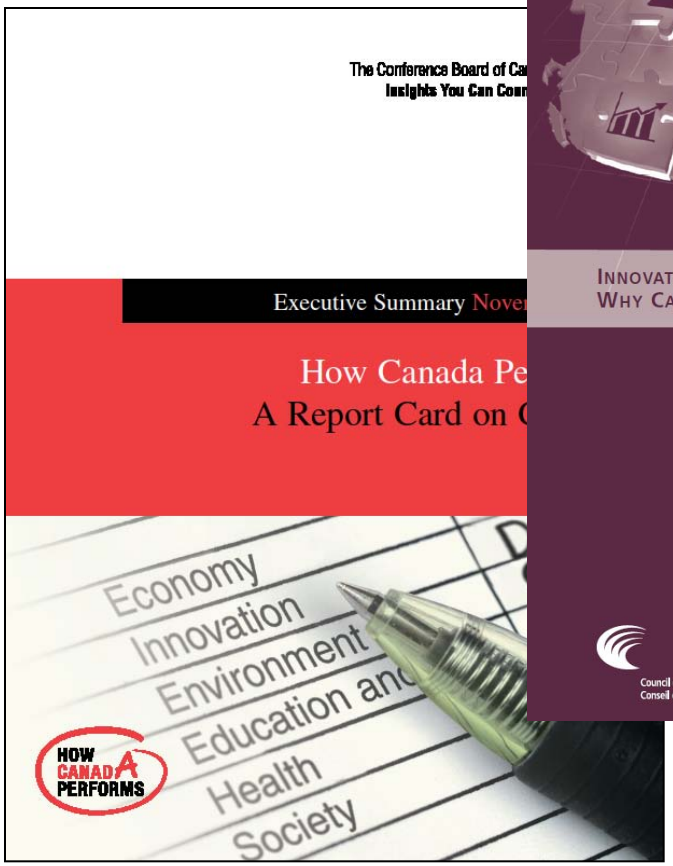
Duderstadt (2008) – Engineering for a Changing World



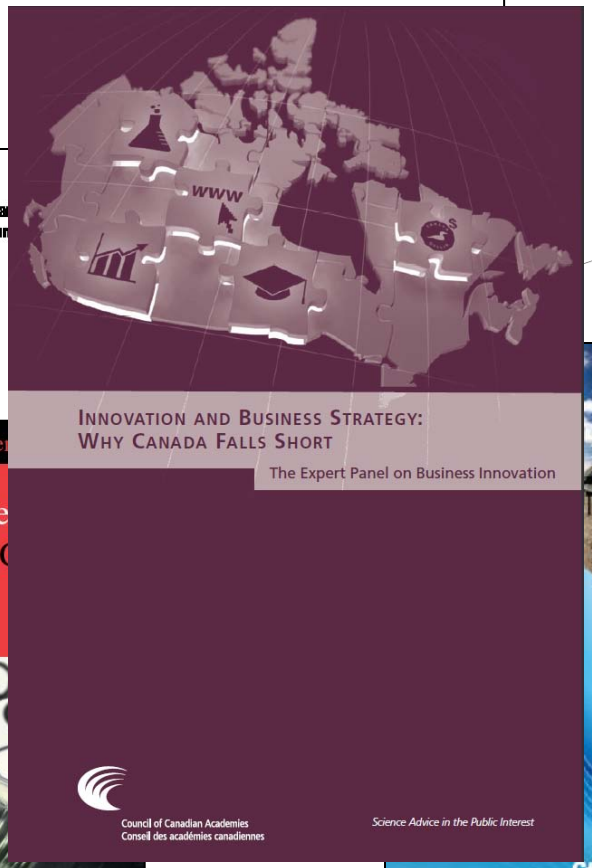
- Preeminence in technological innovation requires leadership in:
  - Engineering research
  - Engineering education
  - Engineering profession
- In a global, knowledge-driven economy, our success or failure will be measured by how well or poorly we do with respect to the innovation agenda
- Engineers are key players in the innovation ecosystem

The Canadian Innovation Challenge

Canada and the Canadian Innovation Eco-System



Nov. 2008



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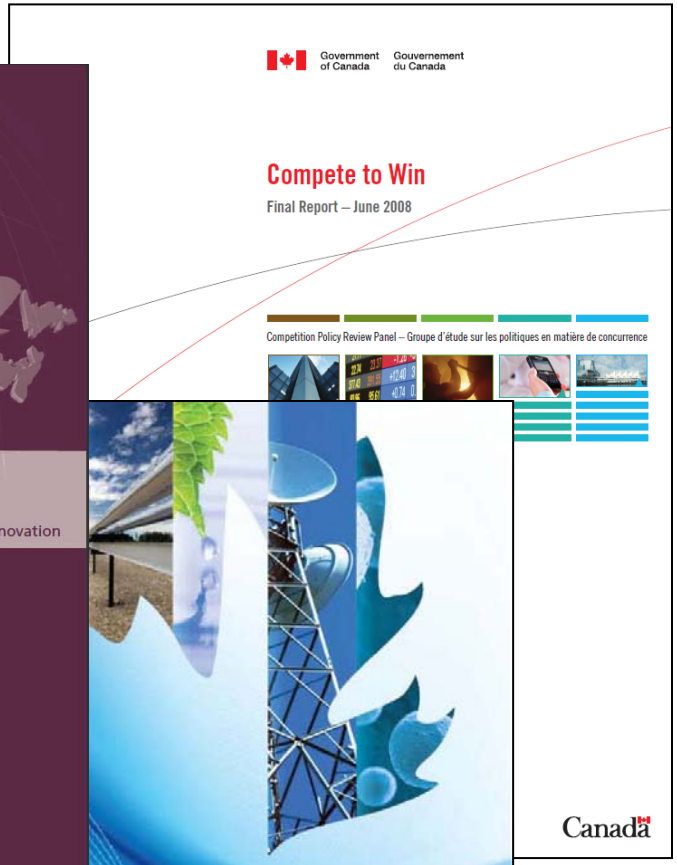

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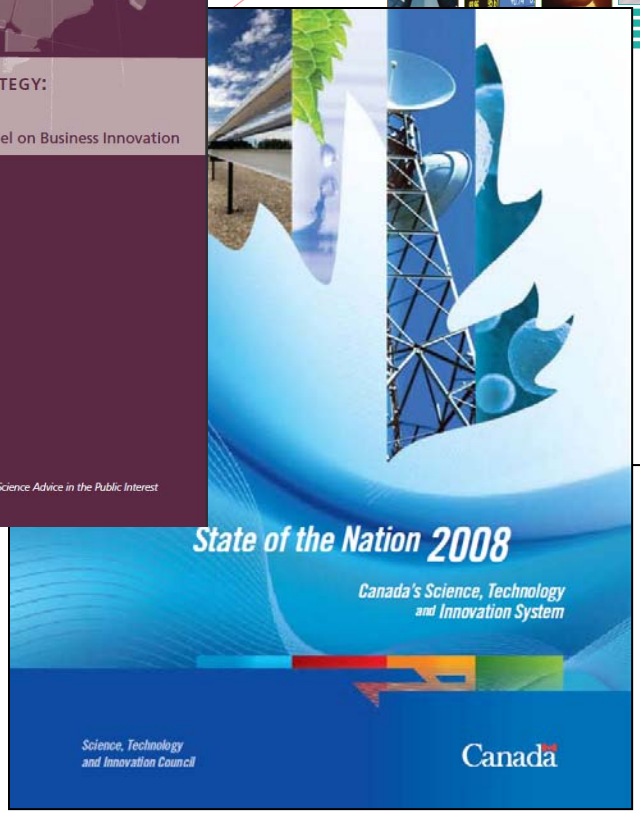

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What is Innovation?

- "Innovation is new or better ways of doing *valued things. Innovation is not limited* to products but includes improved processes like the assembly line, and new business models like web-based commerce. An "invention" is not an innovation until it has been implemented to a meaningful extent." (Council of Canadian Academies, 2009)
- **Innovation is the process by which individuals, companies and** organizations develop, master and use new products, designs, processes and business methods. … The components of innovation include research and development, invention, capital investment and training and development. (STIC, 2008)
- Innovations can be 'transformative' and result in the development of entirely new markets or they can be incremental.

Why is Innovation Important?

Innovation → Productivity → Income → Higher Standard of Living

- "Innovation drives an economy's ability to create more economic value from an hour of work. The resulting productivity growth creates potential for rising wages and incomes, and thus for a higher standard of living." (Council of Canadian Academies, 2009)
- To date we have been fortunate to benefit from a dominant natural resources economy … but that is not the answer!
- In fact, we have failed to innovate in that sector, e.g., pulp and paper industry
- We have also been fortunate to rub shoulders with the up to now, dominant world economy – but for how long?

The Drivers of Innovation

- Some of the drivers of innovation include:
  - a private sector that has science, technology, and innovation strategies at its core;
  - institutions of education and research that develop, recruit, and retain strong talent pools; and
  - researchers who keep us at the forefront of knowledge and workers who see and act on opportunities to work smarter and more creatively

OECD on Canada's Innovation Performance

- "Canada's innovation performance exhibits both strengths and weaknesses.
  - It scores high in terms of the quantity and quality of scientific articles, but
  - the number of triadic patents remains under the OECD and EU25 averages."
- "It performs well in terms of firms with new-to-market product innovations, especially among SMEs, but the share of turnover due to these products is among the lowest in the OECD area."
- "More broadly, productivity growth has become a concern. While labour productivity grew above the OECD average from 1995 to 2000, it has since weakened, with annual growth of 1% in 2001-06, compared to an OECD average of 1.8%."

Triadic Patents

Triadic patents are a family of patents filed at the European Patent Office, the US Patent and Trade Office and the Japan Patent Office.

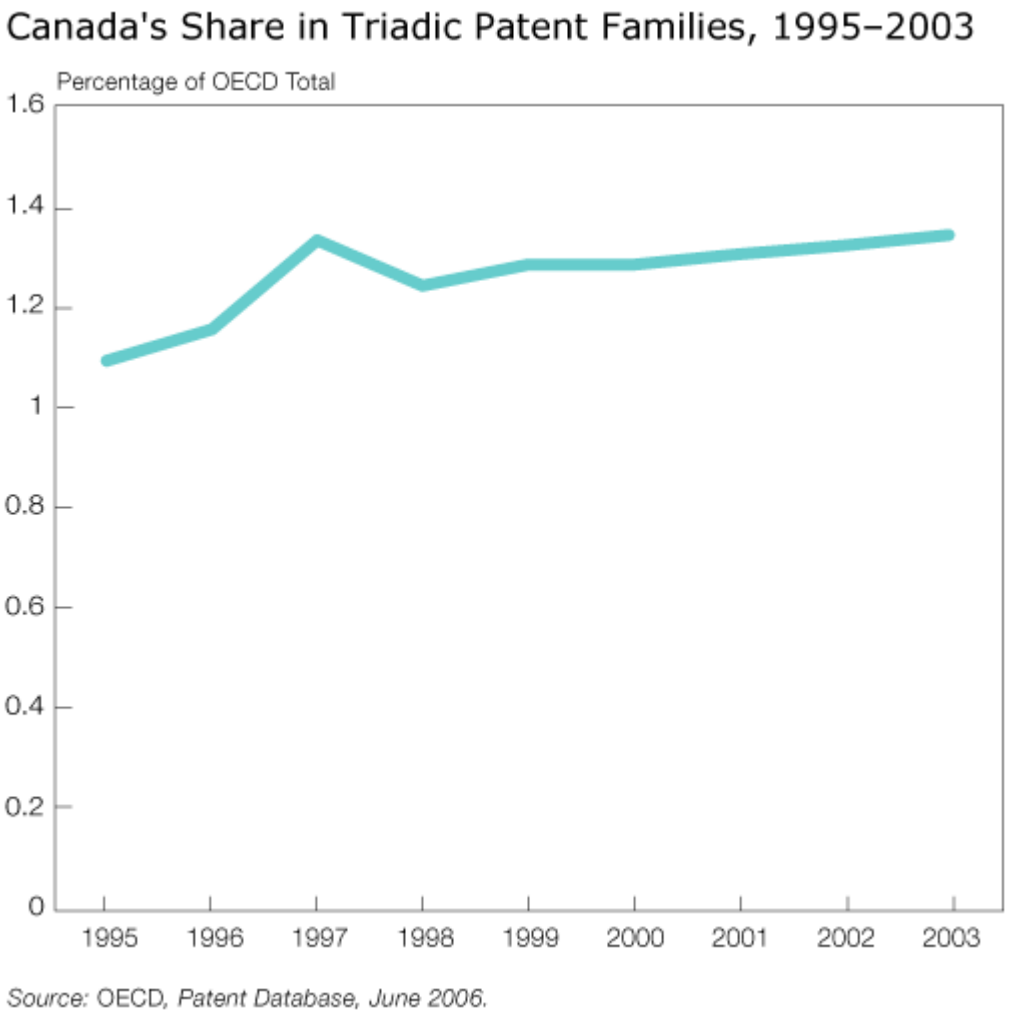
“Shares in triadic patent families are used to measure a country's inventive performance, diffusion of knowledge, and innovative activities. Canada's world share in triadic patent families among the OECD countries grew slightly from 1.13% in 1996 to 1.31% in 2002, peaking at 1.34 % in 1998.

In contrast, the U.S. had the greatest share in 2002 at 36.29%.”

Triadic Patent Families per million population (1991–2001)

Country	Number of Triadic Patent Families per million population (1991)	Number of Triadic Patent Families per million population (2001)
Canada	9.8	20.6
France	30.5	40.3
Germany	46.0	90.7
Italy	11.7	14.8
Japan	71.8	92.3
United Kingdom	21.8	36.7
U.S.	40.0	57.7

(Source: OECD, Science, Technology and Industry: Scoreboard 2005)



Source: OECD, Patent Database, June 2006.

Canada's Innovation Performance Relative to G-7

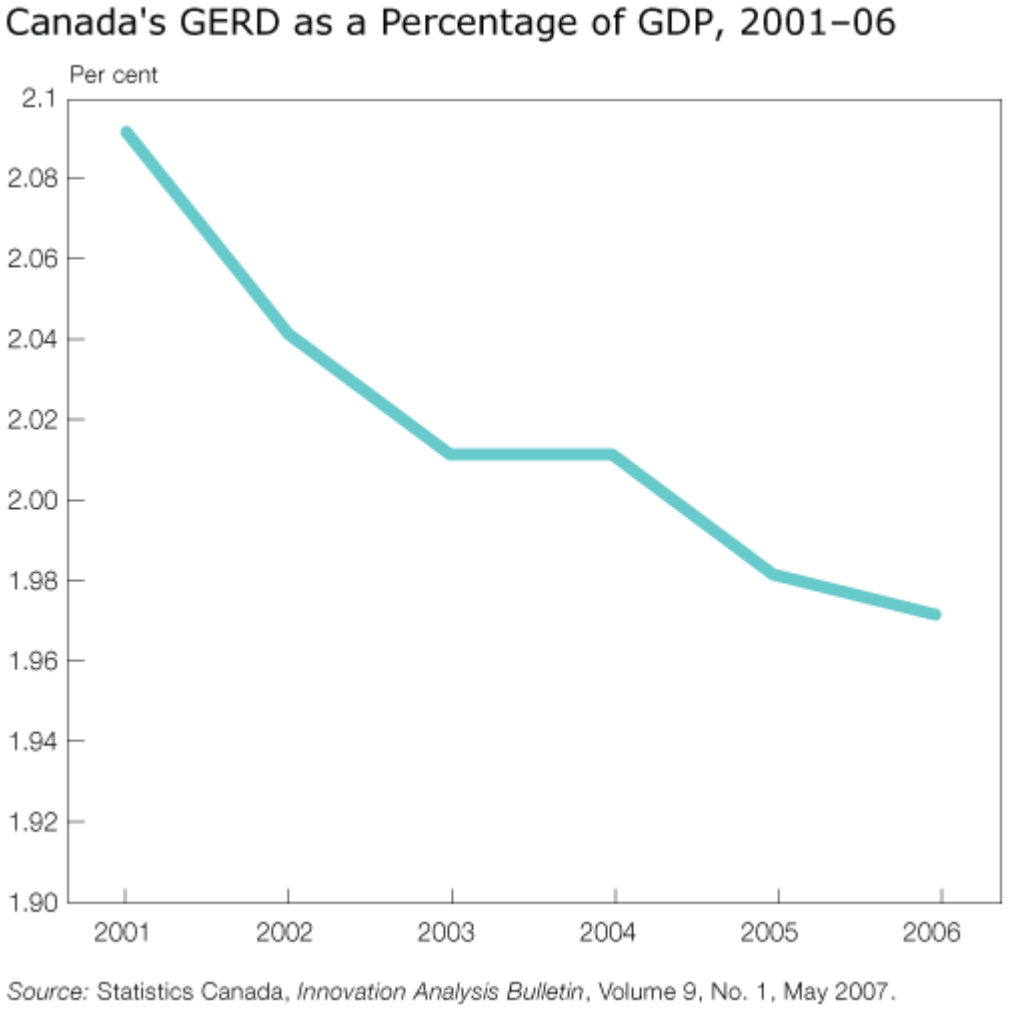
Canada is considerably behind the U.S. and other G-7 countries.

Canada, ranked 14th out of 17 countries in a report by the Conference Board of Canada, scoring relatively poorly on the creation and diffusion of knowledge.

Gross Domestic Expenditures on Research and Development (GERD)

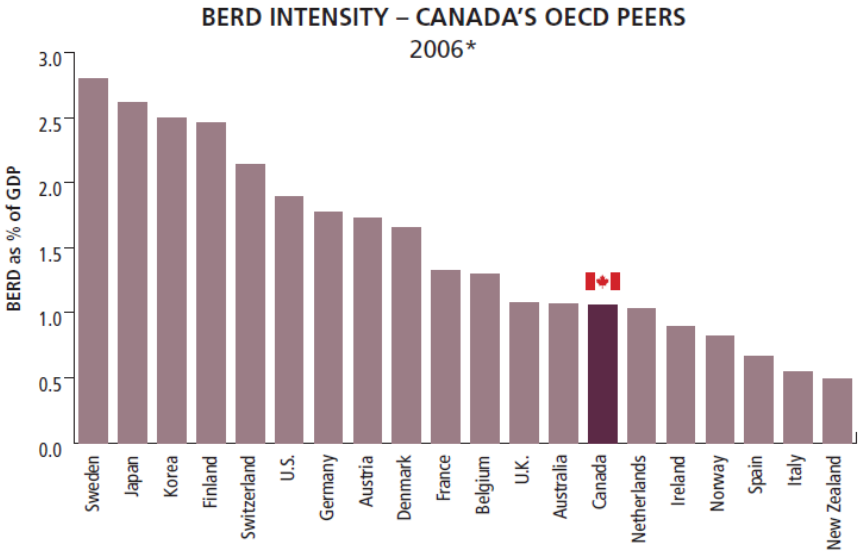
"As a percentage of GDP, GERD was 1.97% in 2006, continuing a downward trend from 2.09% in 2001.

It is increasingly important for Canada to be competitive with other countries that are aggressively increasing their GERD, such as Finland and Japan, both of which by 2002 exceeded 3% GERD as a percentage of GDP, following steady increases since the early 1990s."



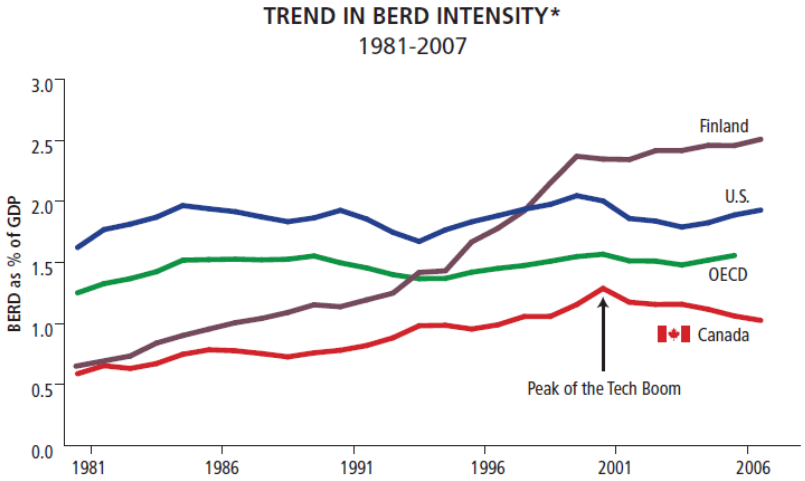
Source: Statistics Canada, *Innovation Analysis Bulletin*, Volume 9, No. 1, May 2007.

Business Expenditures in R&D



*Data for New Zealand are for 2005, and data for Switzerland are for 2004.

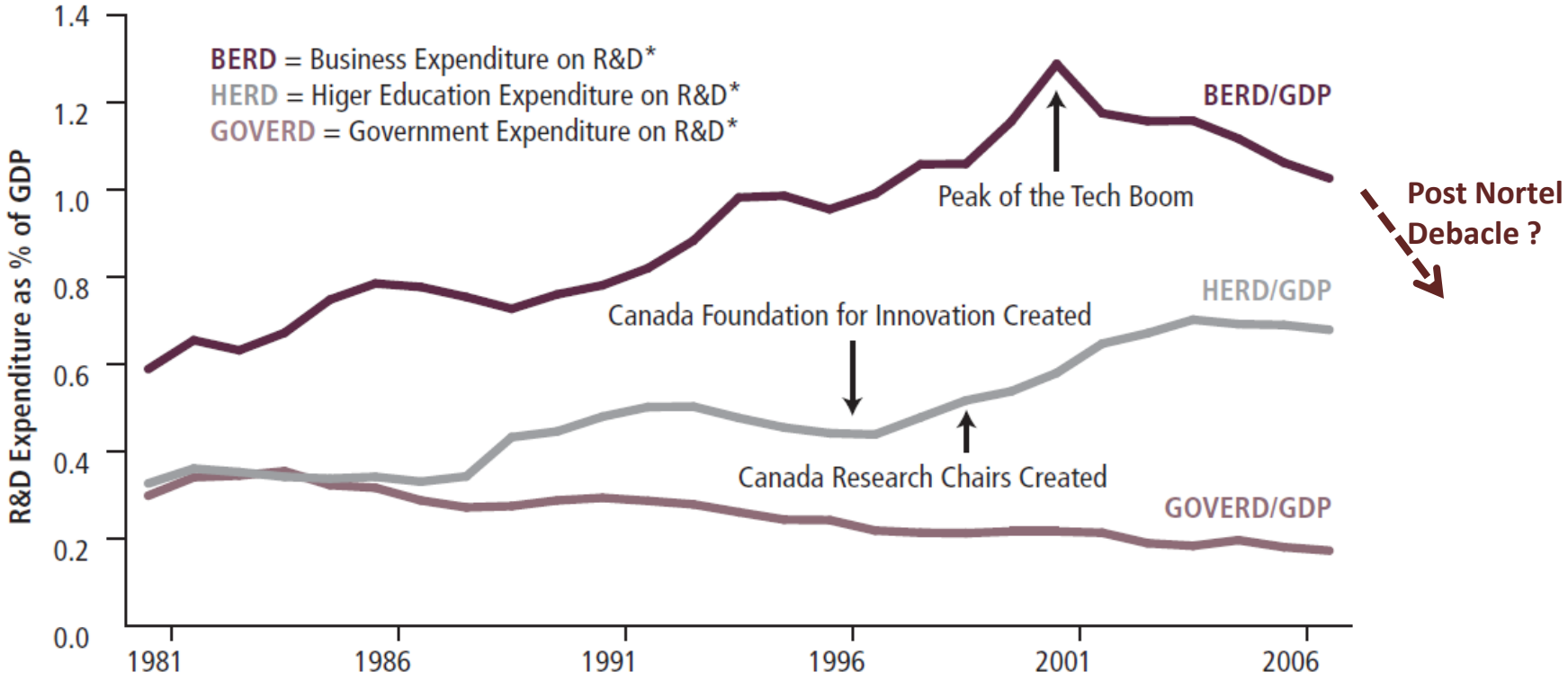
Data Source: OECD, 2008g



*BERD Intensity = Business Expenditure on R&D as a percentage of GDP.

Data Source: OECD, 2008g

Trends in R&D Intensity in Canada 1981-2007



The Canadian Innovation Gap

- We rank poorly across almost all aspects of innovation:
  - the creation of knowledge,
  - the diffusion of knowledge,
  - the transformation of knowledge and
  - the use of knowledge through commercialization. (Compete to Win, 2008)
- While Canada has the highest rate of college completion among its peer group, Canada produces
  - few graduates with advanced degrees (masters and PhD) in science and engineering; and
  - few graduates in business (Conference Board of Canada, 2008)
  - few domestic students interested in graduate engineering studies

Engineering for a Changing World

2008

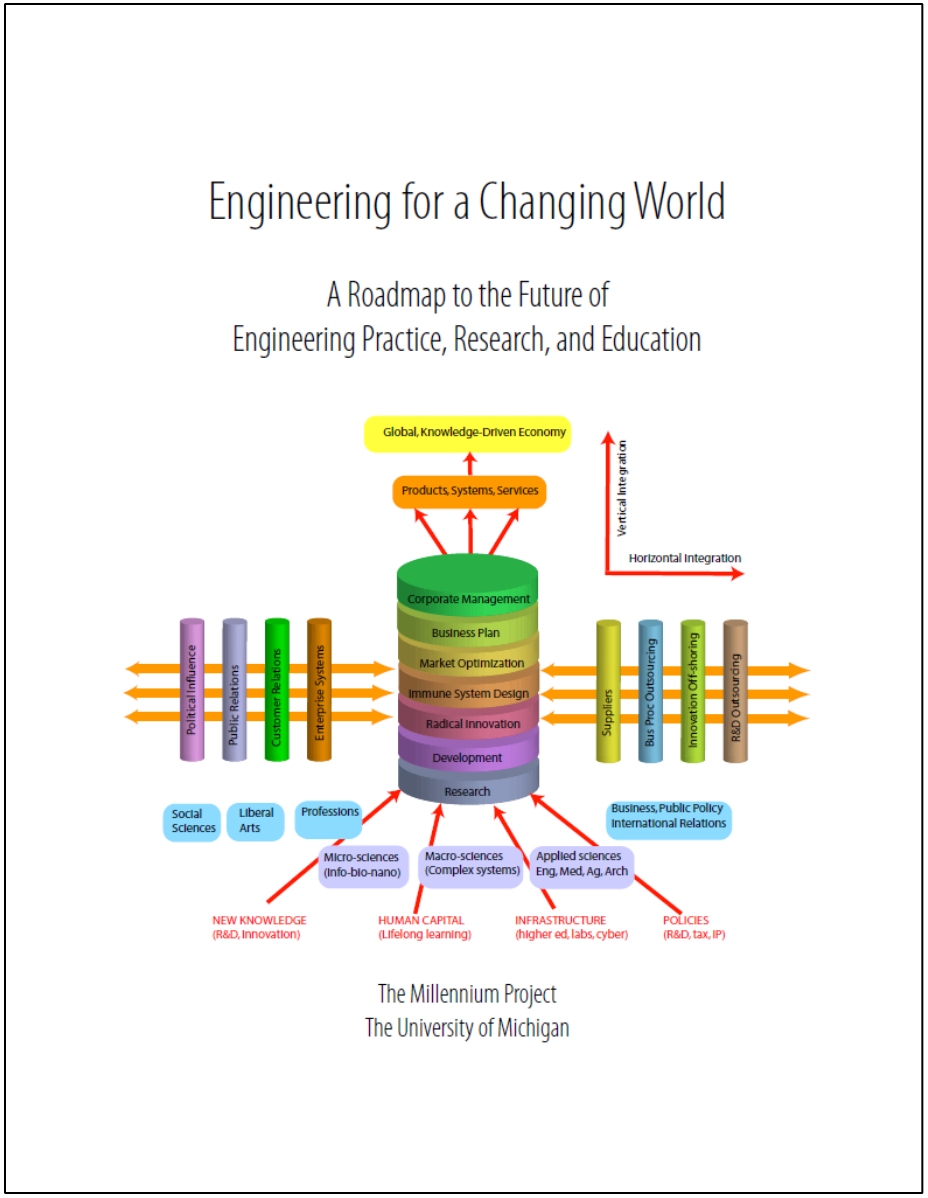
James Duderstadt

President Emeritus and Past Dean of Engineering

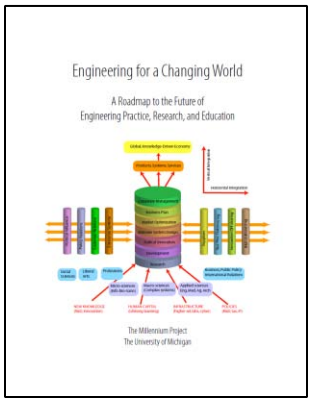
The University of Michigan

The emergence of a global, knowledge driven economy based upon technological innovation … is likely to demand *(demands)* a profound transformation of engineering practice, research and education.

Engineering practice and the technology needs are changing the nature of engineering practice demanding far broader skills than the simply mastering scientific and technological disciplines



The facts …



- Off-shoring of engineering jobs
- The decline of student interest in science and engineering
- The decline in the participation of women in engineering
- The decline in the number of domestic students in graduate studies in engineering
- The lack of visibility of the profession (e.g., law and MD)
- The virtual absence of engineers in the public policy debates

Raises serious questions about the adequacy of our approach to engineering – the profession and education

Leadership in the Engineering Profession

Leadership in the Engineering Profession

However …

It has been said that engineering in this country is an *invisible profession.* This is mainly because most Canadians have only a vague and limited idea of what we do. As a result, our national consciousness is not aware of the role engineers play in medical research advances; in alleviating human suffering; in creating devices such as the Blackberry or the iPod.

Some have argued that Engineering is becoming a 2nd Tier Profession?

- MD … LLB … PEng
  Why is it that we rarely quibble when a lawyer bills us $500+/h by 6 min increments and achieves more than 2000 h per year of effective billing, while a senior consulting will have to negotiate down his hourly rate to below $150/h?

- "Engineers in the early days of the space race used to tell the story that when a rocket launched successfully, it was called a **scientific breakthrough**. But if it exploded on the pad or shortly thereafter, it was called an **engineering failure**." Stephen J. Mraz

http://machinedesign.com/article/changes-in-the-engineering-profession-over-80-years-0407

Engineers and Public Policy

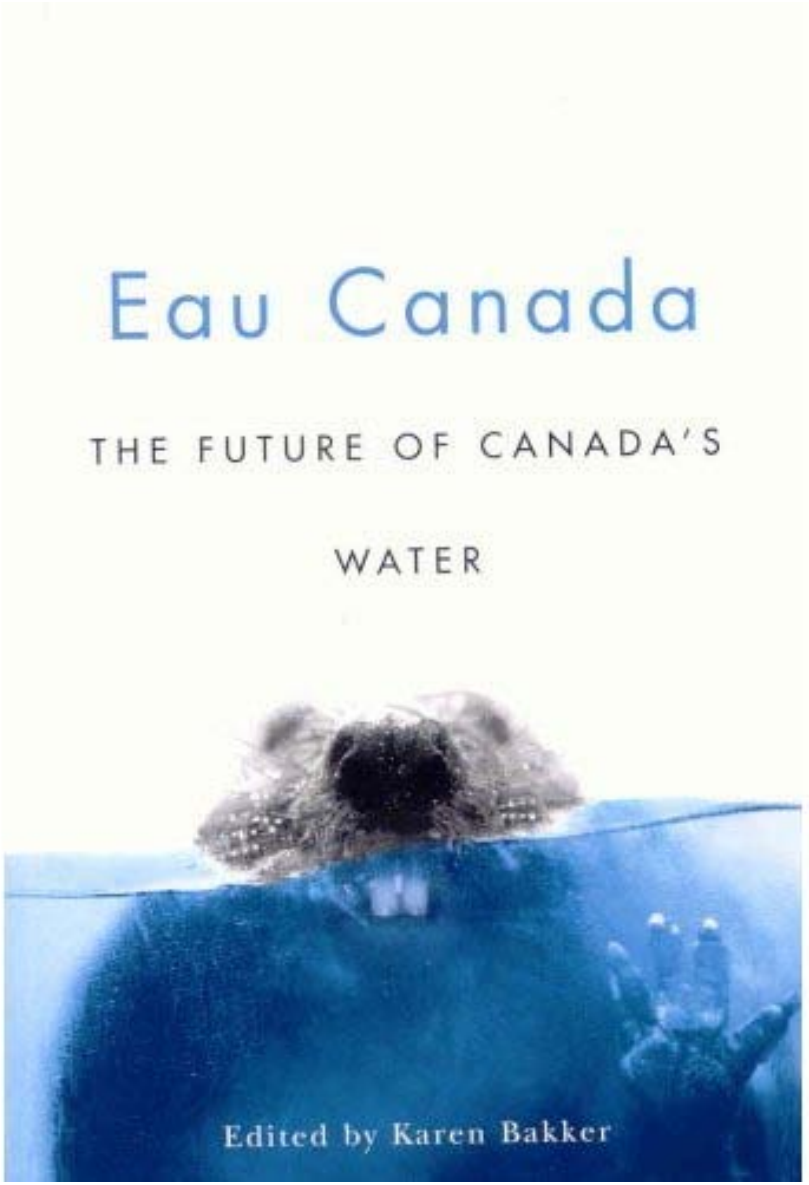
- Why is it that engineers are virtually absent from key public policy decisions involving many scientific and engineering issues, e.g.,
  - Energy
  - Telecommunications
  - Health
  - Environment
  - Water

An Example:
Water Governance

- An excellent book on water governance in Canada (2007)
- 27 contributors addressing issues such as:
  - Water supply
  - Water quality
  - Water commerce
  - Watershed management
  - Wastewater treatment
  - Water rights

  NOT a single engineer

- Let's face it …
  If we do not get involve in the debates, in the shaping of public policies … we risk that they will be set by *individuals that are not fully informed !*



Engineers and Public Policy

- The engagement of engineers in shaping public policies has been virtually non-existent.
  - We should not be surprised - as engineers have never been trained to address, participate or understand such issues
- It is critical that engineers get involve in the development of public policies, to ensure that public policies are based on sound engineering and scientific concepts. At the same time this will allow us to translate complex engineering concepts into a publicly accessible discourse.

Duderstadt (2008) on the Status of the Profession

- "It is essential to elevate the **status** of the engineering profession, providing it with the prestige and influence to play the role it must in an increasing technology-driven world while creating sufficiently flexible and satisfying career paths to attract a diverse population of outstanding students. Of particular interest is greatly enhancing the role of engineers both in influencing policy and popular perceptions and as participants in leadership roles in government and business."

There is hope …

- These observations should not be surprising:
  - Public policy issues have traditionally been addressed by the faculties of social sciences
  - Engineers were not trained on the importance of taking part in the public policy debate

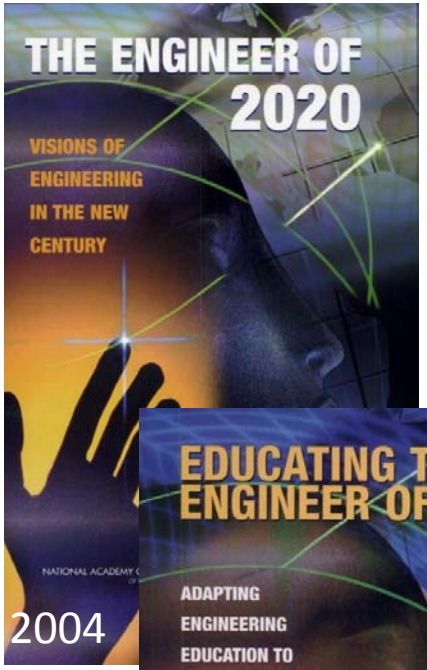
There's hope …

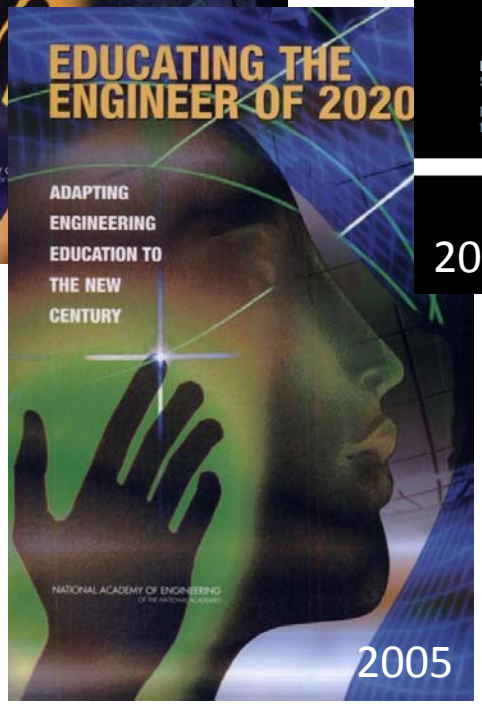
- The creation in 2006 of the Graduate School of Engineering Practice at Mac and the Dofasco Centre for Engineering and Public Policy; and
- The launch in 2008 of the PEO Centre on Engineering and Public Policy.

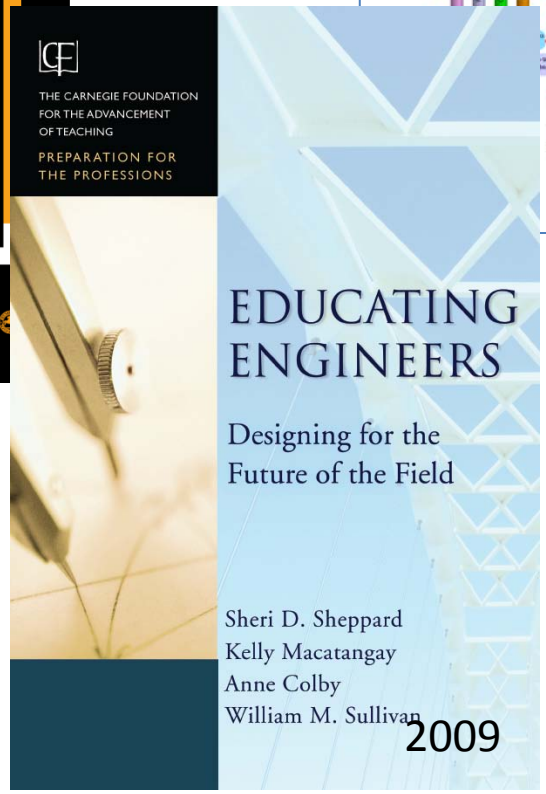
Leadership in the Engineering Profession requires Leadership in Education

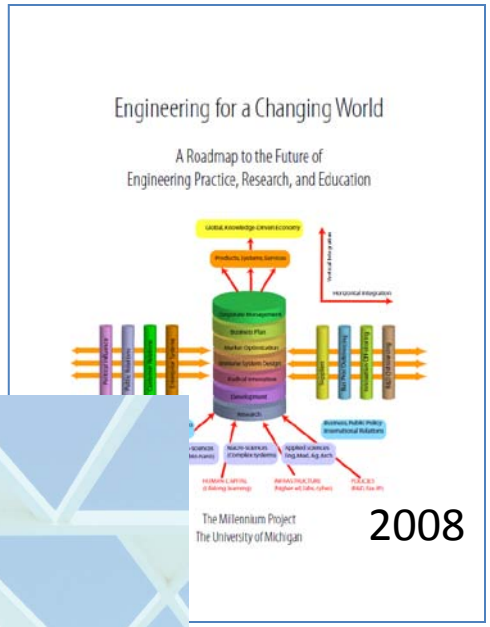
Leadership in Engineering Education

Leadership in Engineering Education









Educating Engineers (2009)

Part of the CF **Preparation for the Professions Project**

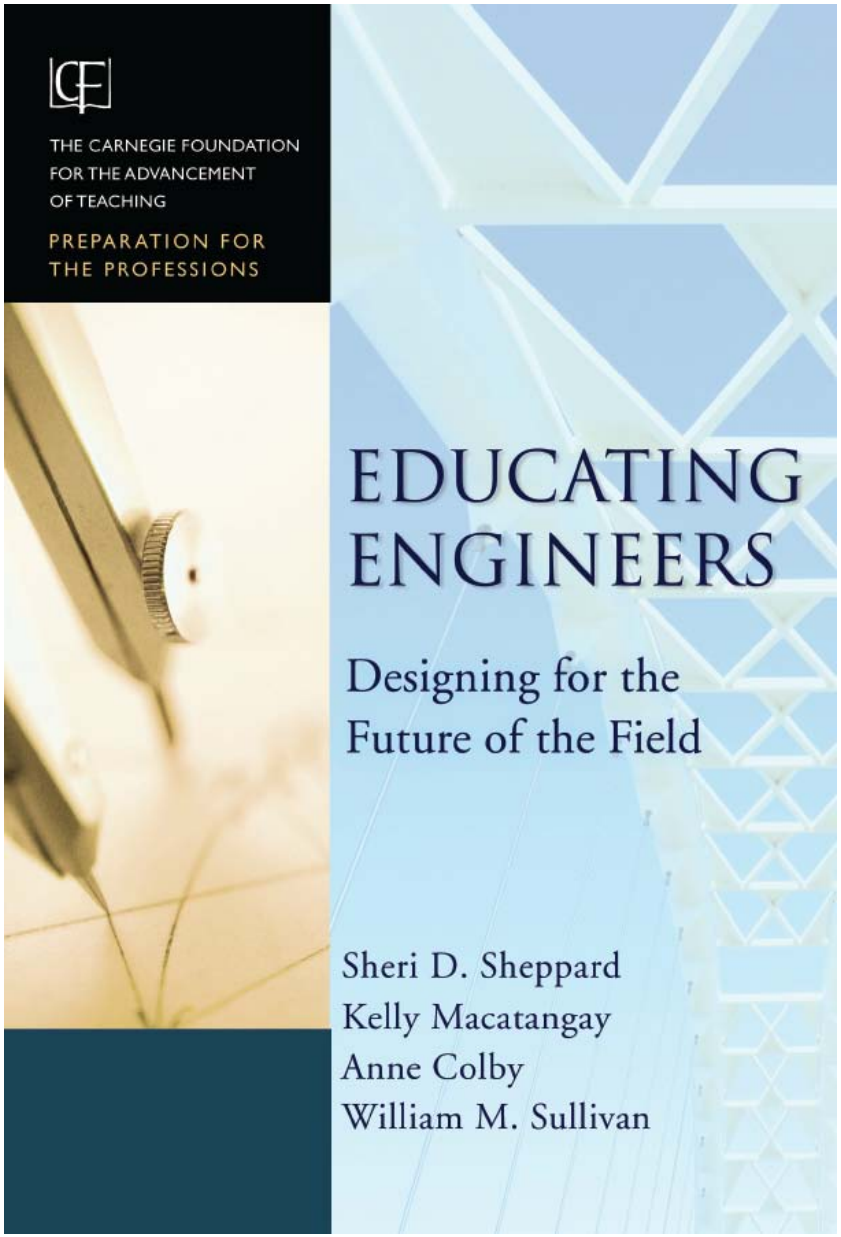
Looking at the education of doctors, engineers, lawyers, nurses, clergy, and teaching.

Characteristics of the Professions:

- Service to others
- Theoretical body of knowledge
- Domain of practice
- Judgment
- Experience
- Professional community

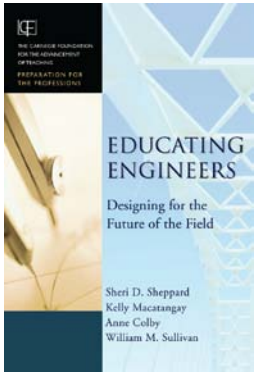
Multidisciplinary-overlapping teams.

Dr. Sheppard presents her report:
http://video.google.com/videoplay?docid=7410299255750354637#



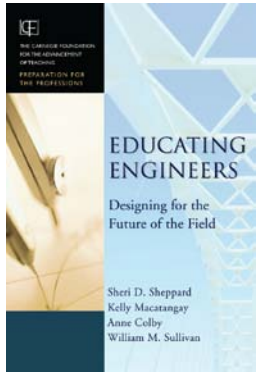
Carnegie Foundation – Educating Engineers

- "Although engineering education is strong on imparting some kinds of knowledge, it is not very effective in preparing students to integrate their knowledge, skills, and identity as developing professionals"



Carnegie Foundation – Educating Engineers

- Aligning Engineering Education to Engineering Practice
- Engineering should be taught as a profession – not as a collection of technical knowledge
- Imperative for teaching for professional practice



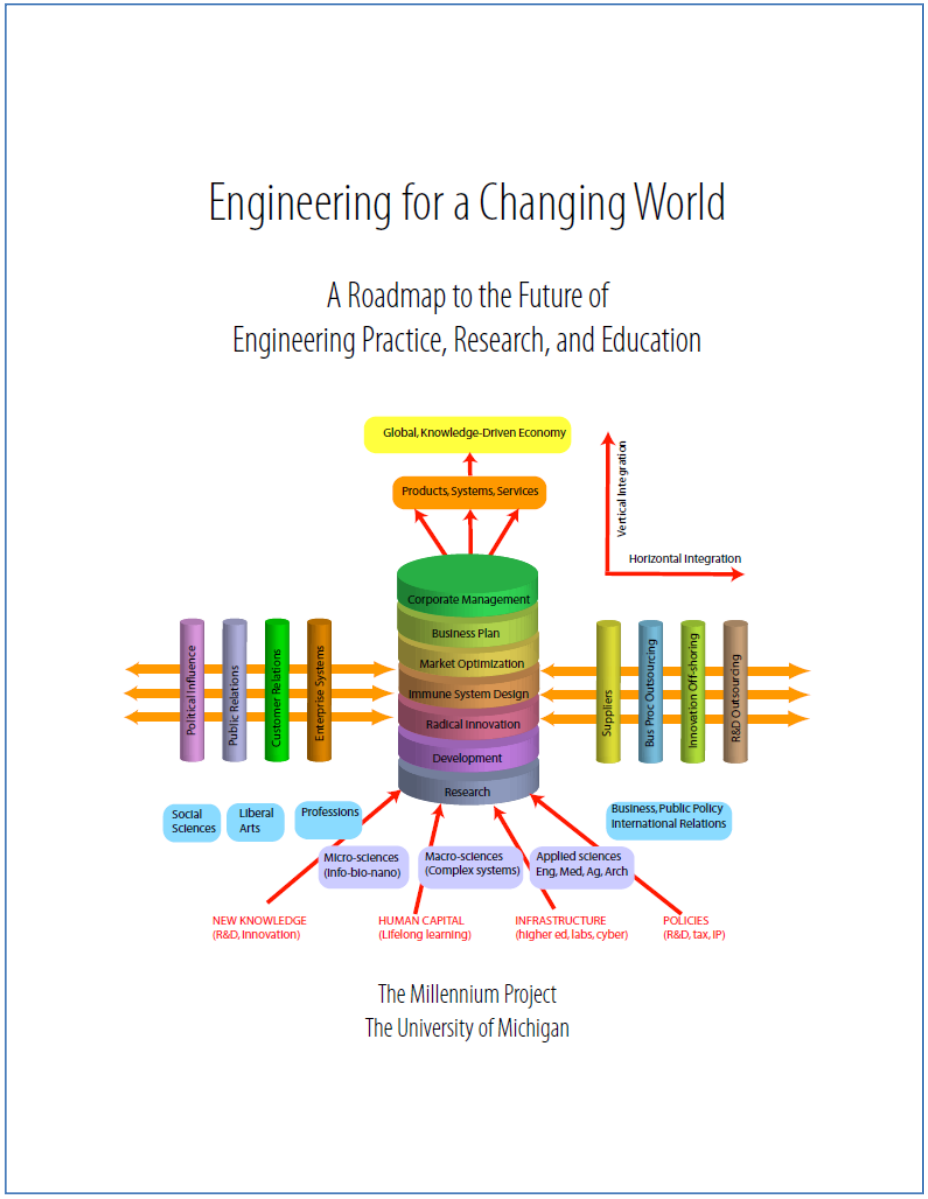
Engineering for a Changing World 2008

Duderstadt provides a comprehensive analysis of Engineering Education, Research and Practice.

Important to broaden the educational experience of engineering students.

Engineers will require a much higher level of education in professional skills such as innovation, entrepreneurship and global engineering practice.

- Establish engineering practice as a true learned profession
- U/G engineering should be configured as an academic discipline similar to other liberal arts disciplines to provide students with more flexibility in their learning experience.
- Establish graduate professional schools of engineering that offer practice-based degrees at the post-baccalaureate level as the entry degree in the profession.



A Multidisciplinary Liberal Arts Approach

- There is a strong consensus that engineers of the 21st century must be broad thinkers who appreciate the global and societal implications of engineering and value the critical links between technology and society.

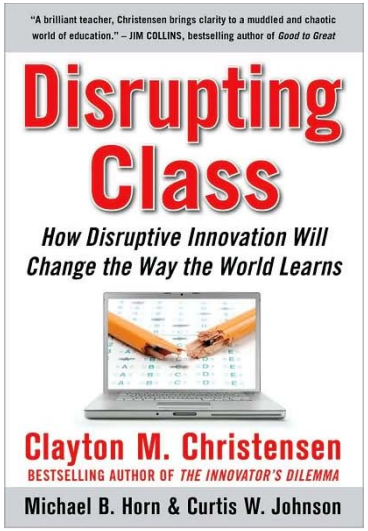
- In 2001, the 2020 Engineering Forum held in Ontario concluded that engineers had to acquire skills leading to "*social, global and political awareness*" and to "*ethical decision making*". It called for a more flexible definition of engineering by promoting interdisciplinarity, a better balance between "technical and artistic training" and more emphasis on teamwork and communication skills.

Leadership in Engineering Education

- If we are to take a leadership role in engineering education we need to **support** and **value** teaching … *after all … that's what it's all about !*
- Universities should take a leadership role in working together to develop state-of-the-art multi-media (self-paced) pedagogical material

Leadership in Engineering Education and Technology

- We are still in the “middle ages” when it comes to the use of technology in engineering education – the technology and the tools are there, the will is not!
- Technology-based learning could be easily be used to address the different learning approaches advocated by Clayton Christensen



Structure of the Engineering Program

- Should Engineering be a 2nd–entry program much like medicine and law?
- This was the case in Quebec until 1966. Before the introduction of the CEGEPs, all students would do a B.A. (Collège classique) prior to admission at École Polytechnique
- Alternatively, we could consider moving to a 5 or 6-year program, i.e., 2 or 3 years of arts/science followed by 3 years of engineering)

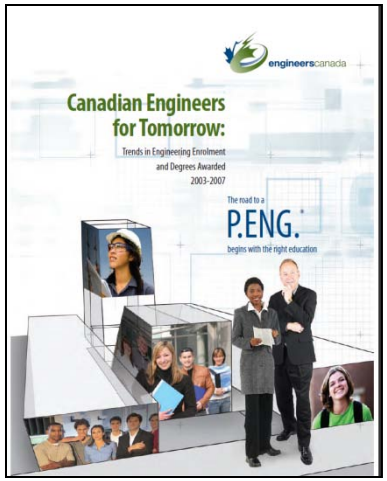
Attracting More Women in Engineering

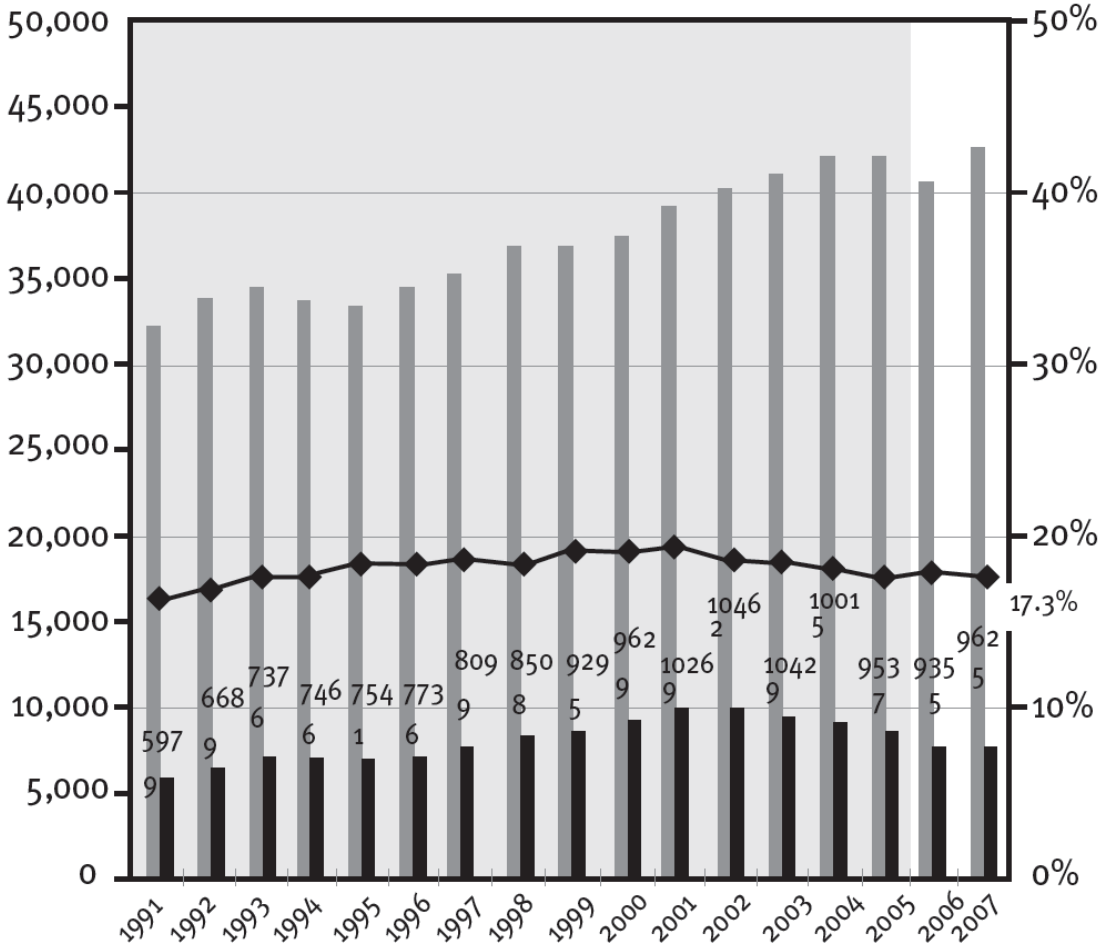
- Incorporating these changes will enable engineering education to respond to another key challenge: *the continuing under-representation of women in engineering*. McMaster, like other universities in Canada and abroad, still faces the continuing under-representation of women in engineering studies. In fact, since 2001, female participation in undergraduate engineering in Canada has fallen from 23 to just 17%.

Undergraduate Enrolment by Gender

Engineers Canada (2009)

"This flattening in enrolment of women presents another question mark in a puzzling trend; the proportion of female engineering students rose for a full 10 years, to a peak of 20.7 percent in 2001, and then began to decline."





Women in Engineering

- Several factors can explain this decline, including an overly rigid and heavily prescriptive curriculum, the enduring image of engineering as a “male-dominated” profession and women’s attraction to the life sciences.
- However, there is ample evidence that a more creative and socially relevant curriculum tends to bring and retain more women into engineering studies.
- Their stronger presence in fields such environmental engineering and biomedical engineering confirms that women tend to internalize engineering as a helping profession.

Graduate Studies

- As indicated earlier, Canada lags most of the OECD countries in the number of masters and PhD students
- Some of the changes suggested previously, i.e., to raise the profile of the profession might also serve to increase the interest of domestic students

NSF Workshop on Improving Domestic Student Participation in Electrical and Computer Engineering Graduate Programs

University Conference Center

Knoxville, TN

October 26-27, 2009

For the past three decades, graduate students in most science and engineering disciplines have been predominantly comprised of foreign nationals. There are many factors that have historically contributed to this reality, some of which are cultural and others driven by market conditions. The field of electrical and computer engineering (ECE), in particular, has undergone substantial changes during this period. Consequently, it has become important to address the demographics of professionals in ECE related fields, as means of understanding what future trends may hold and what national resources are expected to be available. Specifically, increasing the enrollment and retention of domestic students in graduate programs pertaining to electrical engineering, computer engineering and related disciplines, is perceived a national priority. It is directly linked with critical national goals, including creation of new jobs, improvement of the quantity and quality of the technical workforce, and contributing to the robustness of the US economy in a growing global technology-driven marketplace. Thus, the outcomes of this workshop are expected to play an important role in refining future NSF solicitations that support the above-mentioned national agenda.

The goal of this two-day workshop will be to assemble department heads and chairs from a broad range of ECE Ph.D. granting institutions across the nation, to an open discussion on potential avenues of promoting the important common goal of increasing domestic graduate student enrollment and retention. The decision to invite department heads and chairs is driven by the desire to obtain feedback, and target the discussions, directly toward policy makers. Embarking with a focus on ECE is suggested as means of limiting the effort such that any recommendations and conclusions can be disseminated to other science and engineering disciplines. The expected outcome of the workshop is a report detailing all discussions held as well as suggestions for future directions to help sustain interest and momentum generated from the workshop. Moreover, the report will include recommendations for further research and data collection that would provide a research-based justification for graduate program revisions.

Conclusions

- Leadership in Engineering Education
  - There is a need to incorporate a **strong** liberal arts component in engineering education
    - 2nd-entry approach (e.g., law and medicine)
    - 2+3 or 3+3 model
  - A focus on "global" education – addressing such issues as innovation, entrepreneurship, communication, culture, arts, science
  - A curriculum centered on the profession of engineering

Conclusions

- Leadership in the Engineering Profession
  - Engineers need to take on leadership roles
  - Engineers need to help shape public policies

  - If we want to cast away this "*cloak of invisibility*", we need to get the word out about the work we do, so that Canadians fully recognize the benefits we provide for our society.

Conclusions

- Innovation in this country depends on our effectiveness to address these challenges

  Council of Canadian Academies whose mandate it is to "perform independent expert assessment of the science that is relevant to public issues" should undertake an assessment the engineering profession and of engineering education.

1 Canadian Academy of Health Sciences, Canadian Academy of Engineering, and the Royal Society of Canada (The Academy of the Arts, Sciences and Humanities of Canada)

Conclusions

- Increasingly, employers are looking for engineers who are … what they call …. ***"Entrepreneurial integrators"***. That is, c*reative people* who bring together pieces of various disciplines to *make things happen.*

- Those familiar with the history of engineering know that creativity has long been a distinguishing feature of our profession. As Albert Einstein once observed: "scientists investigate **that which *already is;*** engineers create **that which has *never been*.**"

Thank you!