ICT Applications in Higher Engineering (Professional) Education in Digital Era

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Board Member of UNESCO Institute of IT in Education

Paradox in HR Market

- High unemployment rate among new graduates but great shortage of talents in HR market
- 2010 Nobel Prize on Economy was granted for research on the paradox phenomena
- Indication of worldwide significance of the issue
- Winners attribute the paradox to mismatching
- Analysis from other data may not agree with this viewpoint (Manpower)
- Main reason for the paradox -- gap between education and society’s needs
UNESCO Report (1972)

“For the first time in history some societies are beginning to reject many of the products of institutionalized education. ...This shows how easily educational systems can become out of phase.”

Source: Edgar Faure, etc. “Learning to be: The world of education today and tomorrow”, UNESCO, 1972
Talent Shortage - Manpower 2014 Survey

PERCENTAGE HAVING DIFFICULTY FILLING JOBS
Top 10 Jobs Employers Are Having Difficulty Filling

1. Skilled Trade Workers
2. Engineers
3. Technicians
4. Sales Representatives
5. Accounting & Finance Staff
6. Management /Executives
7. Sales Managers
8. IT Staff
9. Office Support Staff
10. Drivers
Reasons for Difficulty Filling Jobs

1. Lack of Hard Skills (35%)
2. Lack of enough applicants (31%)
3. Lack of experiences (25%)
4. Lack of Soft Skills (19%)
Macro Control Model for GPE

Driving force
Policy
Leadership
Resources
...

Profession Education institutions
Program, Curricula, Teachers, Pedagogic method, Contents, ICT tools

Professional HR Market
Society needs
Key stakeholders' needs

Strategies and measures for improvement

assessmen
Student
Program
University

Employment rate and quality
Of graduates
Skills and attributes required by professionals
Huge Gap between Context of Professional Career and Professional Education

1. Philosophy: Education (Educare) vs. “jiaoyu” (教育)

2. Mechanism: Isolated environment from professional career

3. Faculties: very weak professional career experiences and pedagogic training (ICT literacy)

4. Teaching method: Textbook-based instruction vs. Learning by Doing (Maker Space. Hicker’s Space)

What has happened to education?

Courtesy: Dr. Stephen Lu of USC

mass education

mass production

Industrialization

mass production

mass education

Campus

Student

Teacher

Course

Curriculum

Examination

Degree

Factory

is Material

is Worker/Robot

is Production REVENUE

is Assembly Line

is Quality Control

is Finish Product

TUITION

$
Why ICT?

- Mass Production → Customerized Mass Production (Flexible Manufacturing + Computer Integrated Manufacturing)

  Production change: concept, mechanism, organization, management, process

- Mass Education → Personalized Mass Learning: How to realize? MUST BE with ICT tools!
Paradigm for GPE

Goals for Education

- Internationalization
- Learning By Doing
- University-Industry Cooperation

Goals for Engineering Education

- 5E Model

Reform Strategies

- Internationalization
- Learning By Doing
- University-Industry Cooperation

Implementation Models

- Washington Accord
- cdio 12 Standards
- Co-Op Education

Learning Process

- Student-centered, project-based active learning by making use of advance education technology and ICT tools
Experiences from XLP Practice

- Modern ITC infrastructures is not only changing the way individuals learn
- But also affecting the way school administration and institutional learning are being organized
- to better utilize ITC in this connected society, there are three basic trends:
Three basic trends

1. A common learning process data analytical platform
   To enable learners and organizations to capture both process data and learning outcome data, and analyze the effectiveness of related learning activities at a significant scale, therefore enable institutions to identify learning performance trends in a wider range of demographic target groups that were never possible before.
Three basic trends

2. Personalized Data Organization and Personalized Search Functionality

To Enable individuals for better organize one's own data asset, will enable both students and teachers to better realize the value of their digital asset over time.
Three basic trends

3. Distributed data exchange and verification mechanism

Technologies that enables distributed data replication and storage, such as Git and Blockchain are changing the way we consider what is trust-worthy on the Internet. Websites such as Wikipedia, GitHub and Source Forge are becoming a kind of public witness
Conclusions

- To effectively use ICT in professional education, the concept, mechanism, organization, management, pedagogy must be changed.
- ICT can play some role in the above change.
- ICT will play a vital role in new professional education.
“If we teach today as we taught yesterday, we rob our children of tomorrow

—John Dewey

We must continuously improve professional education!
Thank you for your attention!
Desired attributes of an engineer

source: Boeing Management Company

- A good understanding of engineering science fundamentals
- A good understanding of design and manufacturing process
- A multi-disciplinary, systems perspective
- A basic understanding of the context in which engineering is practical
- Good communication skills
- High ethical standards
- Ability to think both critically and creatively—individually and cooperatively
- Flexibility: the ability and self-confidence to adapt to rapid or major changes
- Curiosity and desire to learn for life
- A profound understanding of importance of team work
## THE RETURN ON INVESTMENT

American schools with the best 30-year net ROI over wages earned by a typical high school graduate

<table>
<thead>
<tr>
<th>School</th>
<th>Total cost</th>
<th>ROI</th>
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<tbody>
<tr>
<td>1. MIT</td>
<td>$189,300</td>
<td>$1,688,000</td>
</tr>
<tr>
<td>2. Calif. Inst. of Technology</td>
<td>181,100</td>
<td>1,644,000</td>
</tr>
<tr>
<td>3. Harvard</td>
<td>189,600</td>
<td>1,631,000</td>
</tr>
<tr>
<td>4. Harvey Mudd</td>
<td>187,700</td>
<td>1,627,000</td>
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<tr>
<td>5. Dartmouth</td>
<td>188,400</td>
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<td>6. Stanford</td>
<td>191,800</td>
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<td>7. Princeton</td>
<td>187,700</td>
<td>1,517,000</td>
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<td>8. Yale</td>
<td>194,200</td>
<td>1,392,000</td>
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<tr>
<td>9. Notre Dame</td>
<td>181,900</td>
<td>1,384,000</td>
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<tr>
<td>10. Univ. of Pennsylvania</td>
<td>191,300</td>
<td>1,361,000</td>
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**CRUNCHING THE DATA**

30-year net return on investment is the difference between the amount earned by graduates from 1980 to 2009 and the earnings of a typical high school graduate, after deducting the cost of obtaining an undergraduate degree. It takes into account the likelihood of never graduating. ROI for public schools in the study was calculated using both in-state tuition and out-of-state tuition; figures shown for public schools include both. Total cost includes tuition fees plus other expenses for the number of years it takes most students to graduate.

Investment Status of American College Education

# of engineering Bachelor offered by countries
Rate of Engg. Bachelor vs. All Bachelor
Engineers need both dimensions, and we need to develop education that delivers both.

Pre-1950s: Practice

1960s: Science & practice

1980s: Science

2000: CDIO

Disciplinary Knowledge

Personal and Interpersonal Skills, and Product, Process, and System Building Skills
### Employable rate by multi-national companies among applicants

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<thead>
<tr>
<th>地区</th>
<th>国家</th>
<th>工程师</th>
<th>金融/会计</th>
<th>通才</th>
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<tbody>
<tr>
<td><strong>中欧和东欧</strong></td>
<td>匈牙利</td>
<td>50</td>
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<td>捷克</td>
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<td>波兰</td>
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<td>30</td>
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<td>俄国</td>
<td>10</td>
<td>20</td>
<td>10</td>
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<td><strong>亚洲</strong></td>
<td>马来西亚</td>
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<td></td>
<td>中国</td>
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<td><strong>拉美</strong></td>
<td>墨西哥²</td>
<td>20</td>
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<td>巴西</td>
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1. Suitability rates empirically based on 83 interviews with human-resources (HR) professionals working in countries shown.
2. Mexico is the only country where interview results were adjusted to 20% (from 42%) for engineers and to 25% (from 35%) for finance/accounting employees since interview base was thinner and risk of misunderstandings high.

Source: Interviews with HR managers, HR agencies, and heads of global-resourcing centers; McKinsey Global Institute analysis
Engineers’ ratio to meet needs of multination companies

According to Michael E. Porter in his book "THE COMPETITIVENESS INDEX: WHERE AMERICA STANDS", the ratio of engineers to meet the needs of multination companies is crucial. The diagram illustrates the number of professional engineers available in various countries, highlighting the disparity between supply and demand. For instance, China has more than twice the number of professional engineers compared to the United States, but only 10% of these are suitable. The diagram also shows comparisons for other countries like India, Russia, Japan, the Philippines, Brazil, the UK, Germany, Mexico, Poland, Canada, Malaysia, Hungary, Ireland, and the Czech Republic. The data is from the year 2003.
Strategy 1: Univ.- Industry Coop

• To form a complete chain for talent cultivation
• To meet requirements from Industry
• To introduce industrial profession into education as its context (outcomes, curricula, teaching resource, assessment, .....
• Industry should contribute to education as its human resource strategy
• Government/industry/education/students & parents work together for talent cultivation

This is responsibility of whole society!

Complete talents cannot be fostered in isolated education institution!
Univ.-Industry Coop

2. To form a complete industrial innovation chain
   • New mechanism for innovation
   • Industry—main body for industrial innovation
   • Government—Policy making, services and initial fund
   • University—main body for knowledge innovation
   • Research institute—bridge between knowledge innovation and industrial innovation with tech. transfer
Strategy 3: Learning by doing

- Learning methodology suggested by John Dewey in 1920’s
- Project based learning: Version of LbD for engineering education
- CDIO: a systematic model of PbL
- CDIO (Conceive, Design, Implement, Operate): represents lifecycle of engineering project (product, process, system, and service)
BEST PRACTICE:
THE CDIO STANDARDS

1. The Context
Adoption of the principle that product, process, and system lifecycle development and deployment are the context for engineering education
2. Learning Outcomes
Specific, detailed learning outcomes for personal, interpersonal, and product, process, and system building skills, consistent with program goals and validated by program stakeholders
3. Integrated Curriculum
A curriculum designed with mutually supporting disciplinary subjects, with an explicit plan to integrate personal, interpersonal, and product, process, and system building skills
4. Introduction to Engineering
An introductory course that provides the framework for engineering practice in product, process, and system building, and introduces essential personal and interpersonal skills
5. Design-Implement Experiences
A curriculum that includes two or more design-impliment experiences, including one at a basic level and one at an advanced level
6. Engineering Workspaces
Workspaces and laboratories that support and encourage hands-on learning of product, process, and system building, disciplinary knowledge, and social learning
7. Integrated Learning Experiences
Integrated learning experiences that lead to the acquisition of disciplinary knowledge, as well as personal, interpersonal, and product, process, and system building skills
8. Active Learning
Teaching and learning based on active experiential learning methods
9. Enhancement of Faculty Skills Competence
Actions that enhance faculty competence in personal, interpersonal, and product and system building skills
10. Enhancement of Faculty Teaching Competence
Actions that enhance faculty competence in providing integrated learning experiences, in using active experiential learning methods, and in assessing student learning
11. Learning Assessment
Assessment of student learning in personal, interpersonal, and product, process, and system building skills, as well as in disciplinary knowledge
12. Program Evaluation
A system that evaluates programs against these 12 standards, and provides feedback to students, faculty, and other stakeholders for the purposes of continuous improvement
CDIO Standard 1 -- The Context

Adoption of the principle that product, process, and system lifecycle development and deployment -- *Conceiving, Designing, Implementing and Operating* -- are the context for engineering education

- It’s what engineers do!
- Provides the framework for teaching skills
- Allows deeper learning of the fundamentals
- Helps to attract, motivate, and retain students
Constant characteristics of context in eng’g profession

- Focus on the needs of the customer and society
- Delivery of new products, processes and systems
- Role of invention and new technology in shaping the future
- Use of many disciplines to develop the “solution”
- Need for engineers to work together, to communicate effectively
- Provide leadership in technical endeavors
- Need to work efficiently, within resources and/or profitably
New characteristics of context of engineering profession

- A change from mastery of the environment to stewardship of the environment
- Globalization and international competition
- Fragmentation and geographic dispersion of engineering activities
- The increasingly human-centered nature of engineering practice
- Increasing emphasis on service-oriented engineering industries
- Rapid evolution of technologies, so, future engineers also need to be quick learners
- Companies want their new hires to be productive from the first day on the job.
CDIO Standard 2 -- Learning Outcomes

Specific, detailed learning outcomes for personal and interpersonal skills, and product, process, and system building skills, as well as disciplinary knowledge, consistent with program goals and validated by program stakeholders

- Allows for the design of curriculum
- Serves as the basis of student learning assessment
CDIO SYLLABUS

- Syllabus at 3rd level of detail
- One or two more levels are detailed
- Rational
- Comprehensive
- Peer reviewed
- Basis for design and assessment

<table>
<thead>
<tr>
<th>1</th>
<th>TECHNICAL KNOWLEDGE AND REASONING</th>
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<tbody>
<tr>
<td>1.1</td>
<td>KNOWLEDGE OF UNDERLYING SCIENCES</td>
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<td>1.3</td>
<td>ADVANCED ENGINEERING FUNDAMENTAL KNOWLEDGE</td>
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<tr>
<th>2</th>
<th>PERSONAL AND PROFESSIONAL SKILLS AND ATTRIBUTES</th>
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</thead>
<tbody>
<tr>
<td>2.1</td>
<td>ENGINEERING REASONING AND PROBLEM SOLVING</td>
</tr>
<tr>
<td>2.1.1</td>
<td>Problem Identification and Formulation</td>
</tr>
<tr>
<td>2.1.2</td>
<td>Modeling</td>
</tr>
<tr>
<td>2.1.3</td>
<td>Estimation and Qualitative Analysis</td>
</tr>
<tr>
<td>2.1.4</td>
<td>Analysis With Uncertainty</td>
</tr>
<tr>
<td>2.1.5</td>
<td>Solution and Recommendation</td>
</tr>
<tr>
<td>2.2</td>
<td>EXPERIMENTATION AND KNOWLEDGE DISCOVERY</td>
</tr>
<tr>
<td>2.2.1</td>
<td>Hypothesis Formulation</td>
</tr>
<tr>
<td>2.2.2</td>
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</tr>
<tr>
<td>2.2.3</td>
<td>Experimental Inquiry</td>
</tr>
<tr>
<td>2.2.4</td>
<td>Hypothesis Test, and Defense</td>
</tr>
<tr>
<td>2.3</td>
<td>SYSTEM THINKING</td>
</tr>
<tr>
<td>2.3.1</td>
<td>Thinking Holistically</td>
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<tr>
<td>2.3.2</td>
<td>Emergence and Interactions in Systems</td>
</tr>
<tr>
<td>2.3.3</td>
<td>Prioritization and Focus</td>
</tr>
<tr>
<td>2.3.4</td>
<td>Tradeoffs, Judgment and Balance in Resolution</td>
</tr>
<tr>
<td>2.4</td>
<td>PERSONAL SKILLS AND ATTITUDES</td>
</tr>
<tr>
<td>2.4.1</td>
<td>Initiative and Willingness to Take Risks</td>
</tr>
<tr>
<td>2.4.2</td>
<td>Perseverance and Flexibility</td>
</tr>
<tr>
<td>2.4.3</td>
<td>Creative Thinking</td>
</tr>
<tr>
<td>2.4.4</td>
<td>Critical Thinking</td>
</tr>
<tr>
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<td>Awareness of One’s Personal Knowledge, Skills, and Attitudes</td>
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<tr>
<td>2.4.6</td>
<td>Curiosity and Lifelong Learning</td>
</tr>
<tr>
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<td>Time and Resource Management</td>
</tr>
<tr>
<td>2.5</td>
<td>PROFESSIONAL SKILLS AND ATTITUDES</td>
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<tr>
<td>2.5.1</td>
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</tr>
<tr>
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</tr>
<tr>
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<td>Proactively Planning for One’s Career</td>
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<tr>
<td>2.5.4</td>
<td>Staying Current on World of Engineer</td>
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<th>3</th>
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<td>Team Operation</td>
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<td>Team Growth and Evolution</td>
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<td>Leadership</td>
</tr>
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<td>Electronic/Multimedia Communication</td>
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<tr>
<th>4</th>
<th>CONCEIVING, DESIGNING, IMPLEMENTING AND OPERATING SYSTEMS IN THE ENTERPRISE AND SOCIETAL CONTEXT</th>
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<tr>
<td>4.1</td>
<td>EXTERNAL AND SOCIETAL CONTEXT</td>
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<tr>
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<td>Roles and Responsibility of Engineers</td>
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<td>The Impact of Engineering on Society</td>
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</tr>
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<td>4.1.4</td>
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<tr>
<td>4.2.4</td>
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<tr>
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<td>Setting System Goals and Requirements</td>
</tr>
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</tr>
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<td>4.3.3</td>
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<tr>
<td>4.4.4</td>
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<td>Designing and Optimizing Operations</td>
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<td>4.6.2</td>
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<td>4.6.3</td>
<td>Supporting the System Lifecycle</td>
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<td>Disposal and Life-End Issues</td>
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<tr>
<td>4.6.6</td>
<td>Operations Management</td>
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CDIO Standard 3 -- Integrated Curriculum

A curriculum designed with mutually supporting disciplinary courses, with an explicit plan to integrate personal, interpersonal, and product, process, and system building skills

- Disciplinary courses or modules make explicit connections among related and supporting content and learning outcomes
- Explicit plan identifies ways in which the integration of engineering skills and multidisciplinary connections are to be made
CURRICULUM MODELS

A strict disciplinary curriculum
Organized around disciplines, with no explicit introduction of skills

An integrated curriculum
Organized around disciplines, but with skills and projects interwoven

A problem-based curriculum
Organized around problems, but with disciplines interwoven

An apprenticeship model
Based on projects, with no organized introductions of disciplines

(Disciplines run vertically; projects and skills run horizontally.)
# Sequencing Engineering Skills

## Integration of Skills

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(Schematic, based on the curriculum in Vehicular Engineering at KTH)
CDIO Standard 4 –
Introduction to Engineering

An introductory course that provides the framework for engineering practice in product, process, and system building, and introduces essential personal and interpersonal skills

- learning experiences that introduce personal and interpersonal skills, and product, process, and system building skills
- student acquisition of the skills described in Standard 2
- high levels of student interest in their chosen field of study, demonstrated, for example, in surveys or choices of subsequent elective courses
CDIO Standard 5 – Design-Implement Experiences

A curriculum that includes two or more design-implement experiences, including one at a basic level and one at an advanced level

Design-implement experiences

• Add realism to the curriculum
• Illustrate connections between engineering disciplines
• Foster students’ creative abilities
• Are motivating for students
CDIO Standard 6 - Engineering Workspaces

Workspaces and laboratories that support and encourage hands-on learning of product, process, and system building, disciplinary knowledge, and social learning

- Students are directly engaged in their own learning
- Settings where students learn from each other
- Newly created or remodeled from existing spaces

(See Handbook, p. 9)
CDIO Standard 7 –
Integrated Learning Experiences

Integrated learning experiences that lead to the acquisition of disciplinary knowledge, as well as personal and interpersonal skills, and product, process, and system building skills.

- Curriculum design and learning outcomes can be realized only if the teaching and learning experiences make dual use of student learning time.
- Faculty serve as role models in teaching product, process, and system building skills as well as engineering principles and theory.
CDIO Standard 8 -- Active Learning

Teaching and learning based on active and experiential learning methods

- Engage students directly in thinking and problem solving
- Help students recognize what and how they learn
- Increase student learning motivation
- Help students form habits of lifelong learning
CDIO Standard 9 – Enhancement of Faculty Skills Competence *

Actions that enhance faculty competence in personal and interpersonal skills, and product, process, and system building skills

- Hire faculty with industrial experience
- Give new hires a year to gain experience before beginning program responsibilities
- Create educational programs for current faculty
- Provide faculty with leave to work in industry
- Encourage outside professional activities that give faculty appropriate experiences
- Recruit senior faculty with significant professional engineering experience
CDIO Standard 10 -- Enhancement of Faculty Teaching Competence

Actions that enhance faculty competence in providing integrated learning experiences, in using active experiential learning methods, and in assessing student learning

- Hire faculty with interest in education and ask them to discuss teaching during their interviews
- Encourage faculty to take part in CDIO workshops
- Connect with the teaching and learning centers at your universities
- Invite guest speakers on teaching topics
- Organize coaching by educational professionals or distinguished peers
- Participate in teaching mentorship programs
CDIO Standard 11 - Learning Assessment

Assessment of student learning in personal and interpersonal skills, and product, process, and system building skills, as well as in disciplinary knowledge

- Measure of the extent to which a student has achieved specified learning outcomes
- Faculty usually conduct this assessment within their respective courses
- Uses a variety of methods matched appropriately to learning outcomes
A system that evaluates programs against these twelve standards, and provides feedback to students, faculty, and other stakeholders for the purposes of continuous improvement.

- A variety of program evaluation methods used to gather data from students, instructors, program leaders, alumni, and other key stakeholders.
- A documented continuous improvement process based on results of the program evaluation.
- Data-driven changes as part of a continuous improvement process.
A Case Study of the Best Practice University of Waterloo, the flag of Co-op Education

- Co-op Education since funded (1957-2008)
- 50% of students participate (10000), switch between school and industry every 4 months
- 3500 partners from industry
- High employment rate: 97.6%, high rate of permanent position 91.1% vs. national wide average 77.9%
- Most innovative univ. in Canada, and most appreciated by industry (Bill Gates)
College students learn from a pupil

Interaction between students’ groups

Interaction between students’ groups

Teachers’ team work

Peer discussion

Students or teachers
Learning process management

- Process control by Dynamic Project Control Tool
- Quality control
- Assessment of students performance
College Graduates Follow Up systems
by MyCos Inc., Member of the Board

- Internet based survey system with very high response rate (50%)
- Questionnaires cover broad range of employment quality
- Large scale of sampling: 400 universities/colleges, 10 provinces, 1 million graduates
- Deep analysis on various aspects of higher education
- Necessary perspective for assessment of education performance
- Very useful for evidence-based decision making
- Very important applications of IT in education
Learning by playing in Ningbo Polytech.
Peer instruction
Remote interaction with teacher
There is no evidence that one learns better through ICT if the pedagogy model of schools does not ready with ICT

Prof. Cornu of UNESCO IITE
Policy Briefing by The UNESCO Chair

- Individualized Learning Process has to be supported by ICT tools
- Complex pedagogic process management has to be supported by ICT tools
- Similar to CIMS for flexible manufacturing

ICTs FOR NEW ENGINEERING EDUCATION

CONTENTS:
- Why improve engineering education?
- ICTs for new engineering education
  - Data collection and analysis using ICTs
  - Pedagogy approaches
  - Learning process management
  - Workspace design and Technology Fusion
  - Open Source and Creative Freedom
- Policy strategy
- Conclusion
- References

WHY IMPROVE ENGINEERING EDUCATION?

In October 2010, UNESCO published a comprehensive report on engineering and development, which is the first of its kind by UNESCO. This report spells out the great importance of engineering for human society in addressing and solving global issues, such as poverty, safe and clean energy, climate change, clean drinking water, among many others. It is estimated in the report that some 2.5 million new engineers and technicians will be needed in sub-Saharan Africa alone if that region is to achieve the Millennium Development Goal of improved access to clean water and sanitation by 2015. In North America, and the European Union, there is also a great shortage of engineers for the next 5 years in the order of millions.

These labour shortage problems could be traced to the shortage of graduating engineering students and the quality gap between engineering education and the skill requirements of labour markets. The challenges to engineering education have two folds. First, engineering programmes must become more attractive to draw a sufficient number of students into completing the programmes. Second, engineering programmes must nurture practical skills that answer the timely needs in relevant labour markets.