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

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UNESCO, Paris, March 25, 2015

Paradox in HR Market



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- 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)



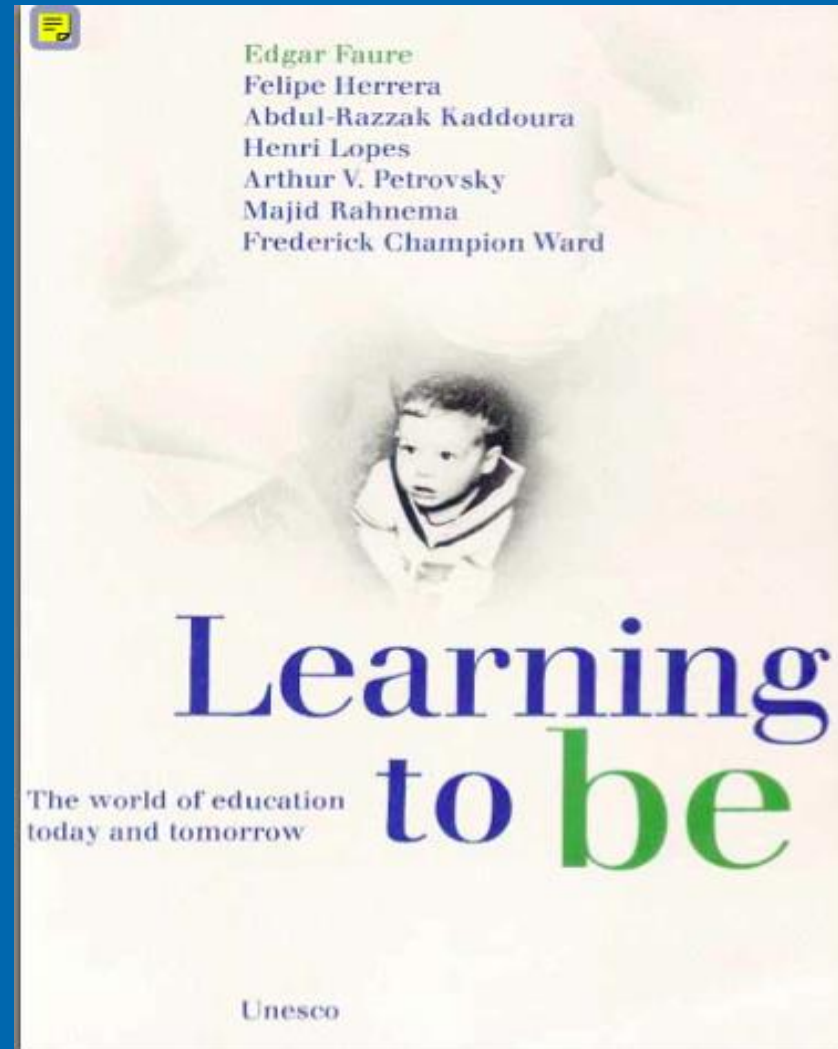
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- “For the first time in history some societies are beginning to reject many of the products of institutionalized education. ... This shows how easily educational systems can become out of phase.”

Source: Edgar Faure, etc. “Learning to be: The world of education today and tomorrow”, UNESCO, 1972



Talent Shortage - Manpower 2014 Survey



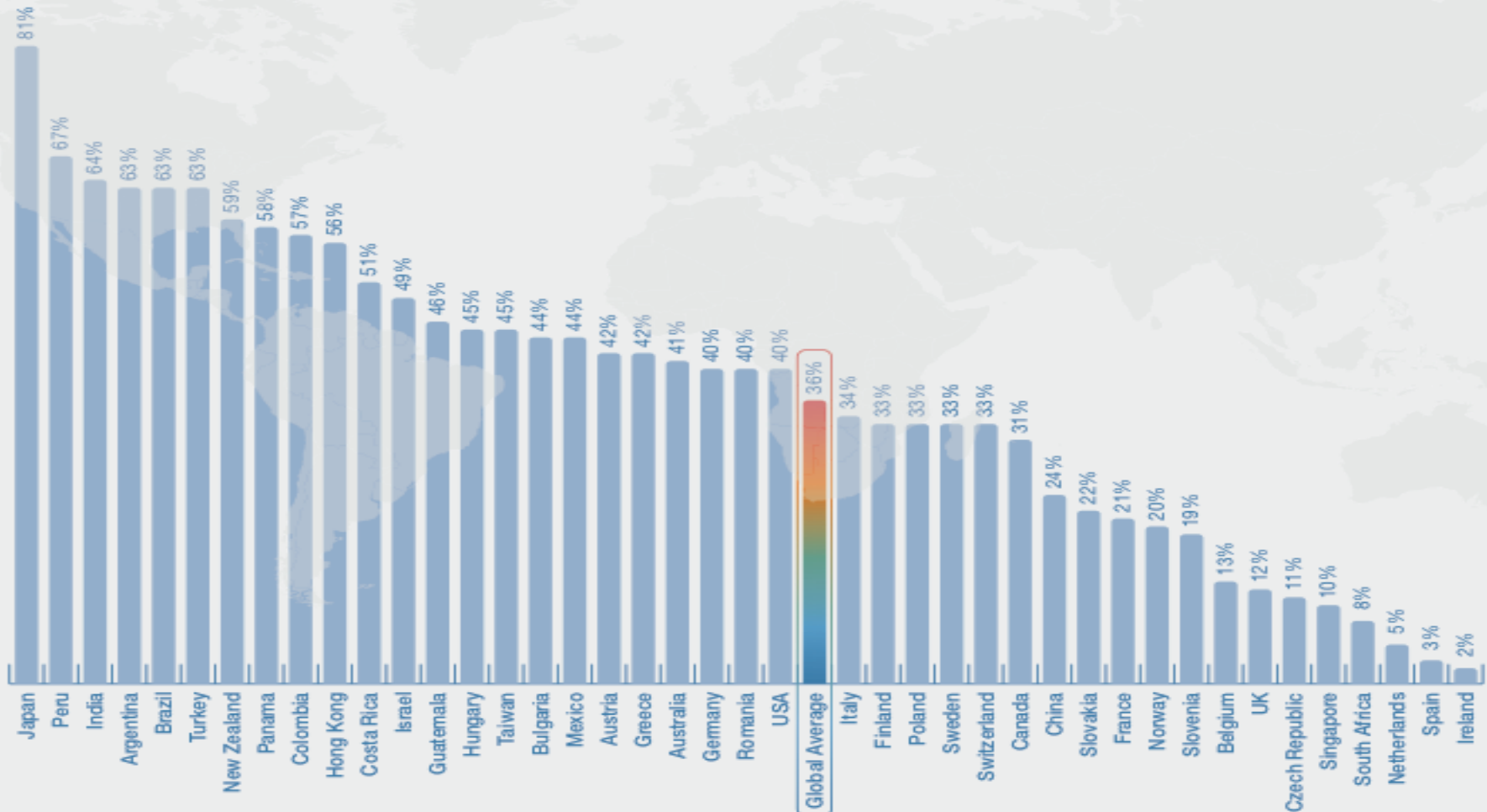
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PERCENTAGE HAVING DIFFICULTY FILLING JOBS



Top 10 Jobs Employers Are Having Difficulty Filling



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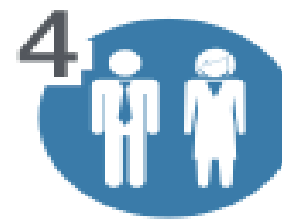
1
Skilled Trade
Workers



2
Engineers



3
Technicians



4
Sales
Representa-
tives



5
Accounting
& Finance
Staff



6
Management
/Executives



7
Sales
Managers



8
IT Staff



9
Office
Support
Staff



10
Drivers

Reasons for Difficulty Filling Jobs



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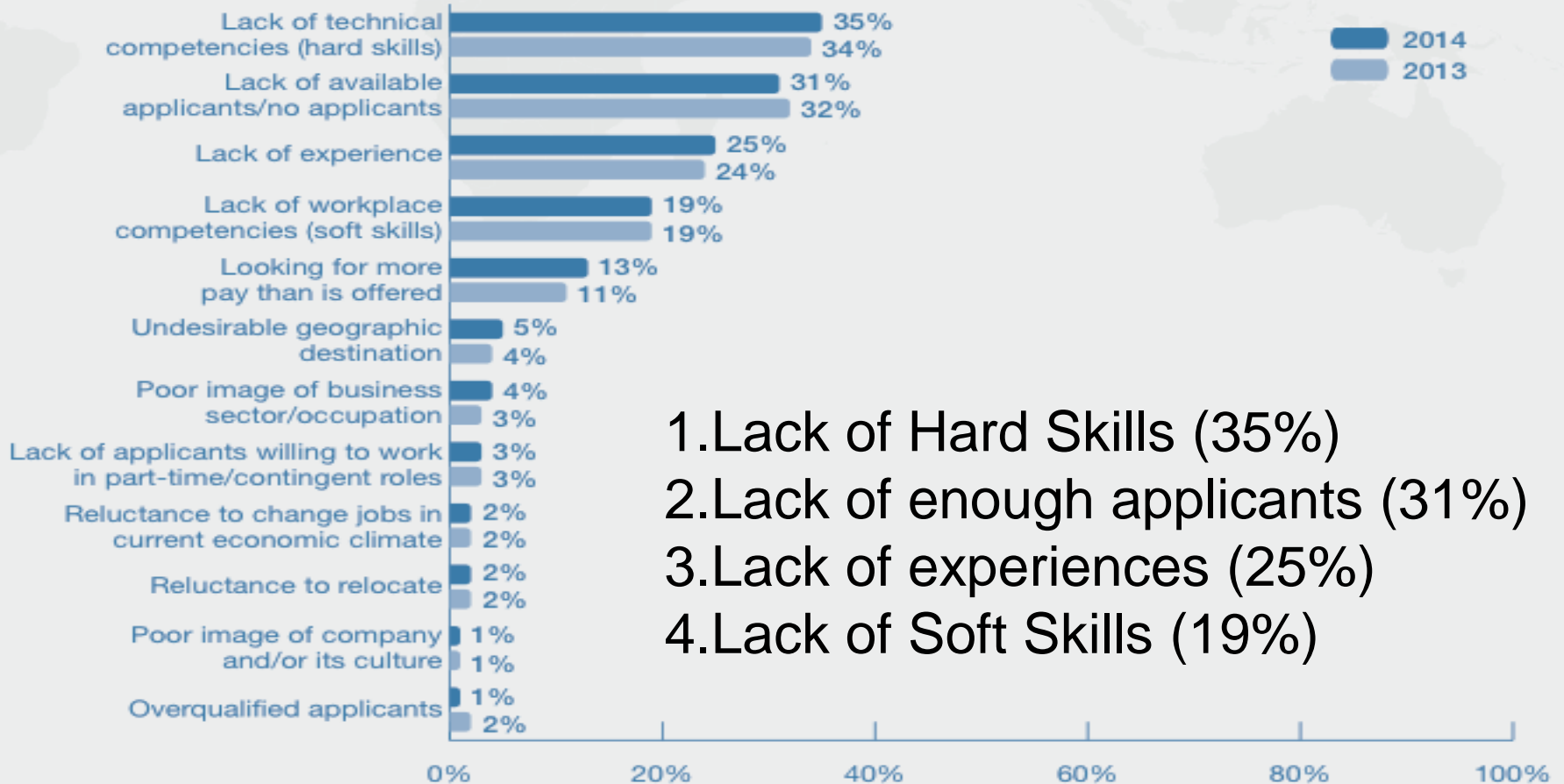
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REASONS FOR DIFFICULTY FILLING JOBS

WHY ARE YOU HAVING DIFFICULTY FILLING THIS SPECIFIC JOB?

Global (Base: all having difficulty filling jobs – 16,272)



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

FIGURE 5

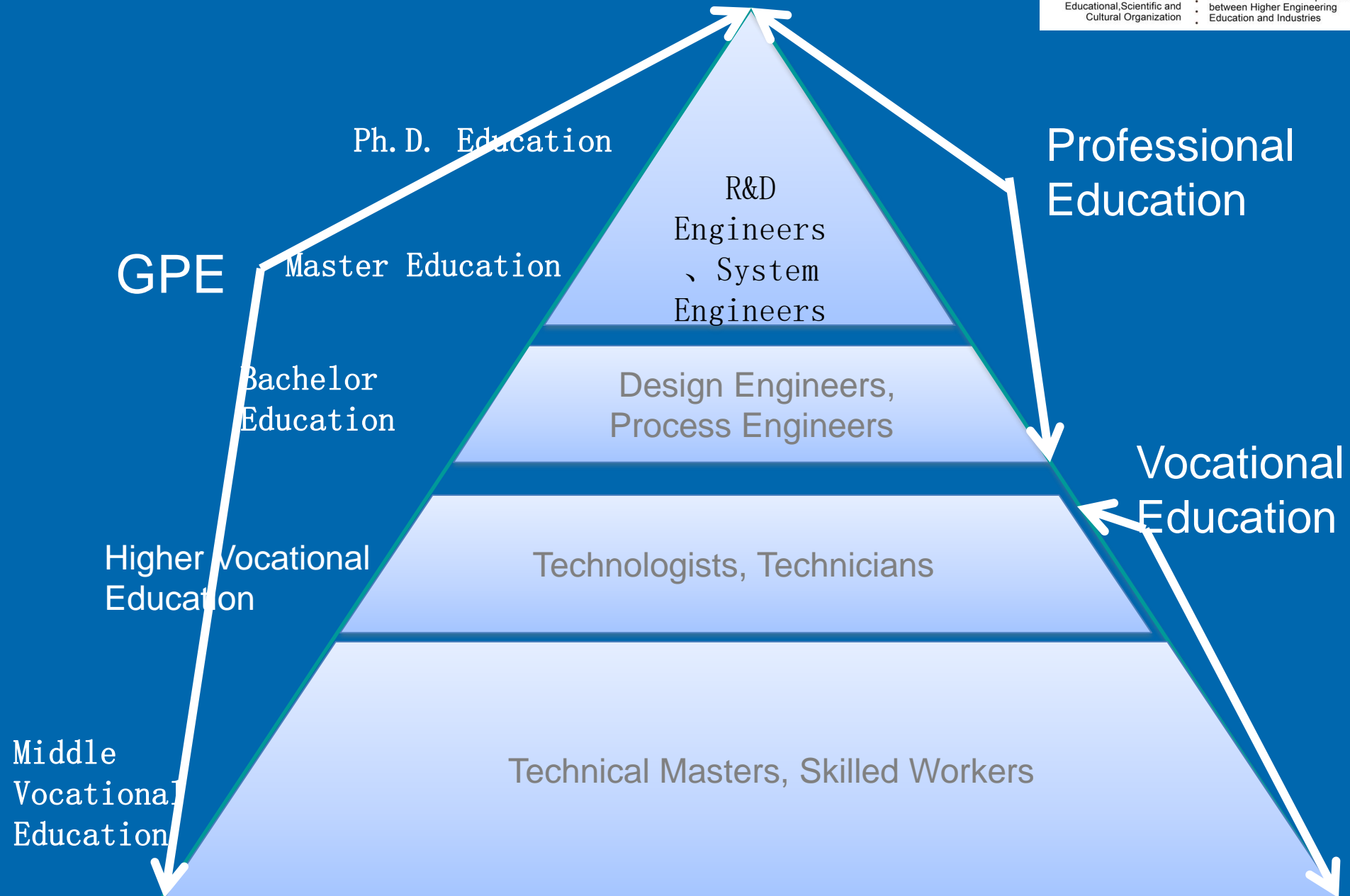
Generalized Professional Education (GPE)



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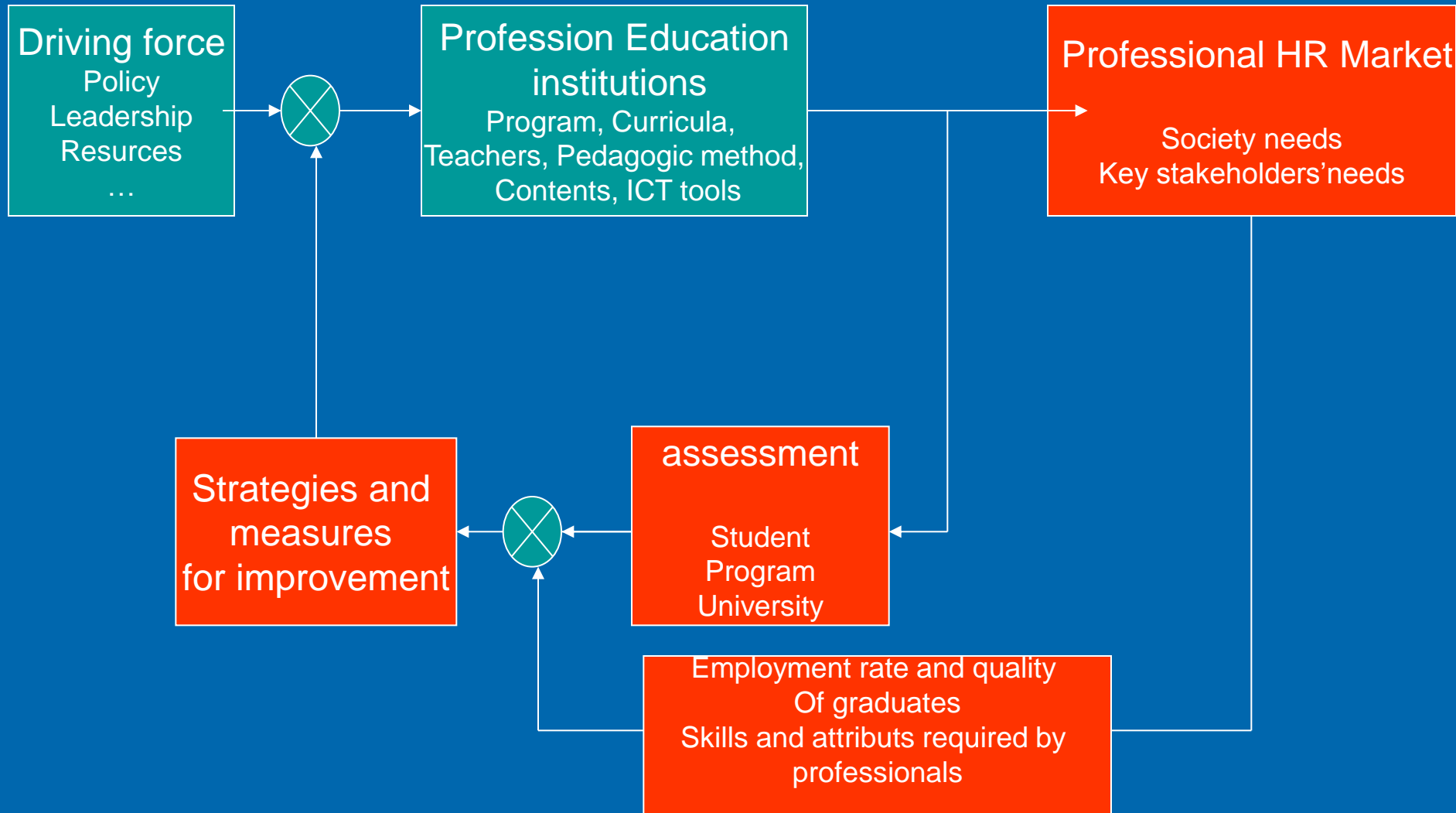
Macro Control Model for GPE



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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)
5. Assessment: Close-book theoretical exams. Vs. Learning Process & Outcomes Evaluation



What has happened to education?

Courtesy: Dr. Stephen Lu of USC



Industrialization

	Campus	Factory	
	Student	is Material	
	Teacher	is Worker/Robot	\$
	Course	is Production	REVENUE
TUITION	Curriculum	is Assembly Line	
?	Examination	is Quality Control	
	Degree	is Finish Product	





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Why ICT?

- Mass Production → Customized 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



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Goals for Education



- Four Pillars
- Learning to know
- Learning to do
- Learning to live together
- Learning to be

Goals for Engineering Education

5E Model



Reform Strategies

Internationalization

Learning By Doing

University-Industry Cooperation

Implementation Models

Washington Accord



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 vital role in new professional education



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“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-independently 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



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School	Total cost	ROI
1. MIT	\$189,300	\$1,688,000
2. Calif. Inst. of Technology	181,100	1,644,000
3. Harvard	189,600	1,631,000
4. Harvey Mudd	187,700	1,627,000
5. Dartmouth	188,400	1,587,000
6. Stanford	191,800	1,565,000
7. Princeton	187,700	1,517,000
8. Yale	194,200	1,392,000
9. Notre Dame	181,900	1,384,000
10. Univ. of Pennsylvania	191,300	1,361,000

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.

Reference: Louis Lavelle. College Degrees Get an Audit. Bloomberg Businessweek, June 28 –July 4, 2010, P15.

Investment Status of American College Education



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Colleges Compared

30-year net return
on investment

Ivies

\$1.4mn

Non-Ivies

\$384.4k

Public Colleges

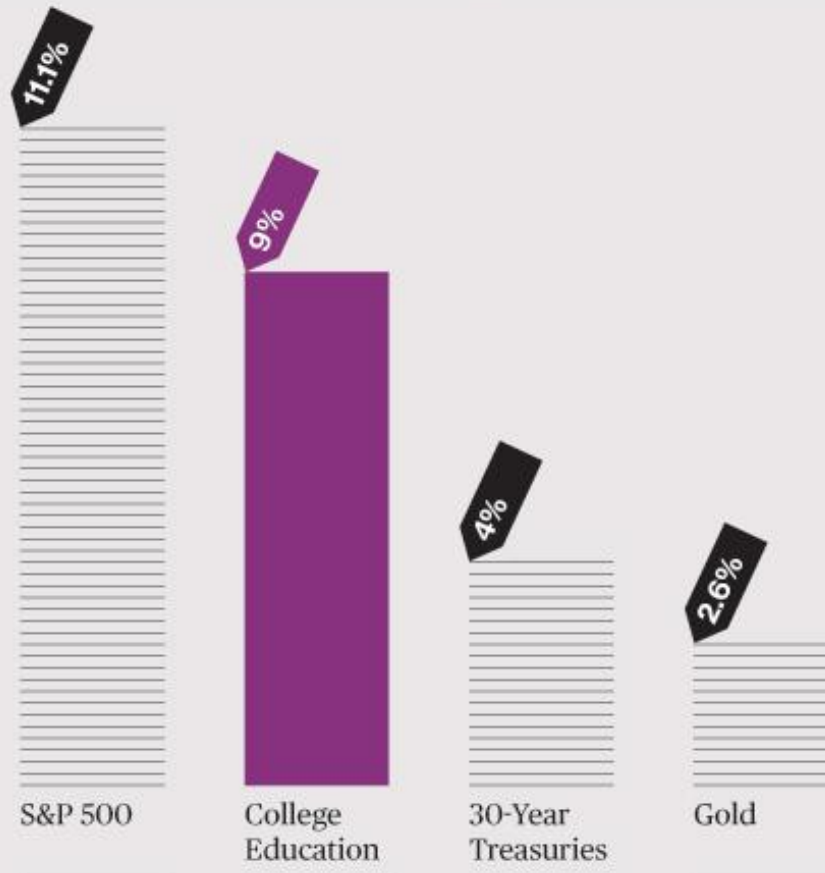
\$322.5k

Private Colleges

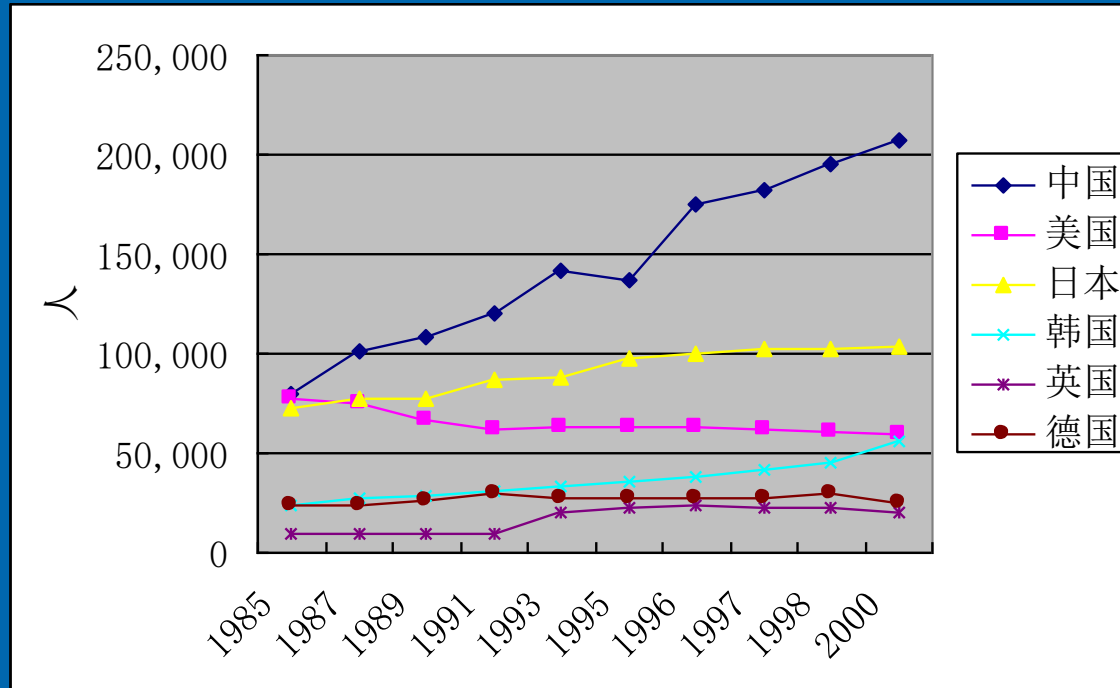
\$559.2k

How a College Education Stacks Up

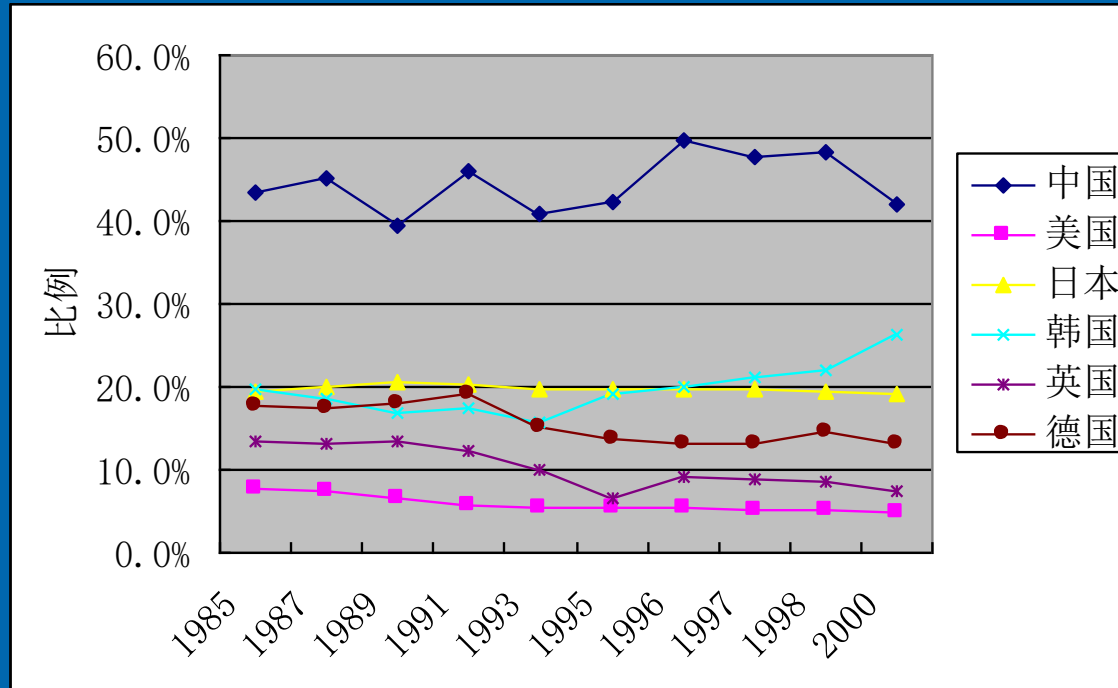
Return on investment of a college degree vs. other investments



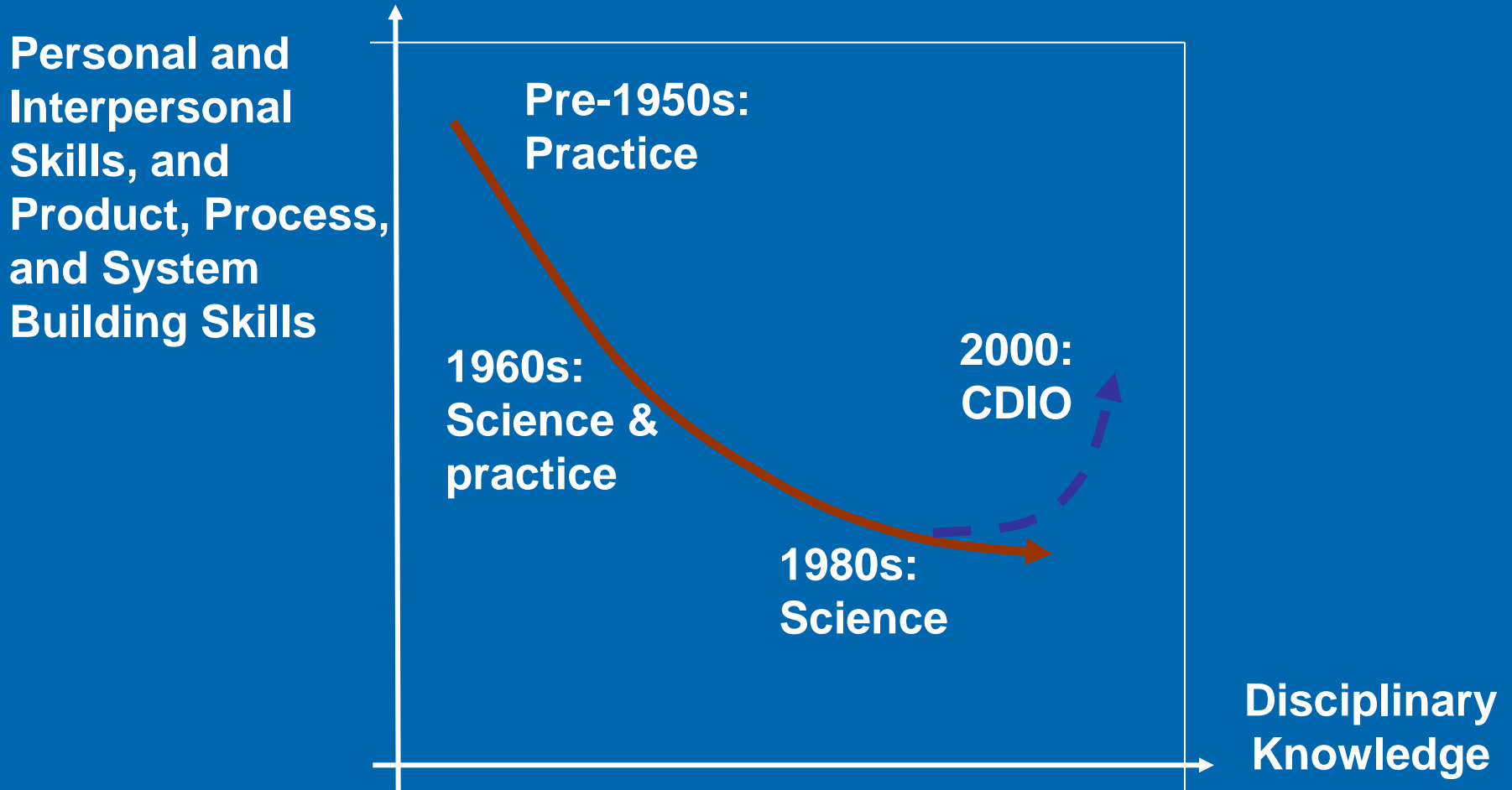
of engineering Bachelor offered by countries



Rate of Engg. Bachelor vs. All Bachelor



NATIONAL DEVELOPMENT OF ENGINEERING EDUCATION



Engineers need *both* dimensions, and we need to develop education that delivers both



Employable rate by multi-national companies among applicants

地区	国家	工程师	金融/会计	通才
中欧和东欧	匈牙利	50	50	30
	捷克	50	40	20
	波兰	50	30	15
	俄国	10	20	10
亚洲	马来西亚	35	25	20
	印度	25	15	10
	菲律宾	20	30	25
	中国	10	15	3
拉美	墨西哥 ²	20	25	11
南美	巴西	13	13	8

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

适合为跨国公司工作的
职业工程师人数
单位：千（2003）

中国的职业工程师总人数是美国的
两倍多.....但只有10%是合适的



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



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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





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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-implement 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



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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



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- 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.





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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



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

- 1 TECHNICAL KNOWLEDGE AND REASONING**
 - 1.1. KNOWLEDGE OF UNDERLYING SCIENCES
 - 1.2. CORE ENGINEERING FUNDAMENTAL KNOWLEDGE
 - 1.3. ADVANCED ENGINEERING FUNDAMENTAL KNOWLEDGE
- 2 PERSONAL AND PROFESSIONAL SKILLS AND ATTRIBUTES**
 - 2.1. ENGINEERING REASONING AND PROBLEM SOLVING
 - 2.1.1. Problem Identification and Formulation
 - 2.1.2. Modeling
 - 2.1.3. Estimation and Qualitative Analysis
 - 2.1.4. Analysis With Uncertainty
 - 2.1.5. Solution and Recommendation
 - 2.2. EXPERIMENTATION AND KNOWLEDGE DISCOVERY
 - 2.2.1. Hypothesis Formulation
 - 2.2.2. Survey of Print and Electronic Literature
 - 2.2.3. Experimental Inquiry
 - 2.2.4. Hypothesis Test, and Defense
 - 2.3. SYSTEM THINKING
 - 2.3.1. Thinking Holistically
 - 2.3.2. Emergence and Interactions in Systems
 - 2.3.3. Prioritization and Focus
 - 2.3.4. Tradeoffs, Judgment and Balance in Resolution
 - 2.4. PERSONAL SKILLS AND ATTITUDES
 - 2.4.1. Initiative and Willingness to Take Risks
 - 2.4.2. Perseverance and Flexibility
 - 2.4.3. Creative Thinking
 - 2.4.4. Critical Thinking
 - 2.4.5. Awareness of One's Personal Knowledge, Skills, and Attitudes
 - 2.4.6. Curiosity and Lifelong Learning
 - 2.4.7. Time and Resource Management
 - 2.5. PROFESSIONAL SKILLS AND ATTITUDES
 - 2.5.1. Professional Ethics, Integrity, Responsibility and Accountability
 - 2.5.2. Professional Behavior
 - 2.5.3. Proactively Planning for One's Career
 - 2.5.4. Staying Current on World of Engineer
- 3 INTERPERSONAL SKILLS: TEAMWORK AND COMMUNICATION**
 - 3.1. TEAMWORK
 - 3.1.1. Forming Effective Teams
 - 3.1.2. Team Operation
 - 3.1.3. Team Growth and Evolution
 - 3.1.4. Leadership
 - 3.1.5. Technical Teaming
 - 3.2. COMMUNICATION
 - 3.2.1. Communication Strategy
 - 3.2.2. Communication Structure
 - 3.2.3. Written Communication
 - 3.2.4. Electronic/Multimedia Communication
 - 3.2.5. Graphical Communication
 - 3.2.6. Oral Presentation and Interpersonal Communication
- 3.3. COMMUNICATION IN FOREIGN LANGUAGES**
 - 3.3.1. English
 - 3.3.2. Languages within the European Union
 - 3.3.3. Languages outside the European Union
- 4 CONCEIVING, DESIGNING, IMPLEMENTING AND OPERATING SYSTEMS IN THE ENTERPRISE AND SOCIETAL CONTEXT**
 - 4.1. EXTERNAL AND SOCIETAL CONTEXT
 - 4.1.1. Roles and Responsibility of Engineers
 - 4.1.2. The Impact of Engineering on Society
 - 4.1.3. Society's Regulation of Engineering
 - 4.1.4. The Historical and Cultural Context
 - 4.1.5. Contemporary Issues and Values
 - 4.1.6. Developing a Global Perspective
 - 4.2. ENTERPRISE AND BUSINESS CONTEXT
 - 4.2.1. Appreciating Different Enterprise Cultures
 - 4.2.2. Enterprise Strategy, Goals and Planning
 - 4.2.3. Technical Entrepreneurship
 - 4.2.4. Working Successfully in Organizations
 - 4.3. CONCEIVING AND ENGINEERING SYSTEMS
 - 4.3.1. Setting System Goals and Requirements
 - 4.3.2. Defining Function, Concept and Architecture
 - 4.3.3. Modeling of System and Ensuring Goals Can Be Met
 - 4.3.4. Development Project Management
 - 4.4. DESIGNING
 - 4.4.1. The Design Process
 - 4.4.2. The Design Process Phasing and Approaches
 - 4.4.3. Utilization of Knowledge in Design
 - 4.4.4. Disciplinary Design
 - 4.4.5. Multidisciplinary Design
 - 4.4.6. Multi-objective Design
 - 4.5. IMPLEMENTING
 - 4.5.1. Designing the Implementation Process
 - 4.5.2. Hardware Manufacturing Process
 - 4.5.3. Software Implementing Process
 - 4.5.4. Hardware Software Integration
 - 4.5.5. Test, Verification, Validation and Certification
 - 4.5.6. Implementation Management
 - 4.6. OPERATING
 - 4.6.1. Designing and Optimizing Operations
 - 4.6.2. Training and Operations
 - 4.6.3. Supporting the System Lifecycle
 - 4.6.4. System Improvement and Evolution
 - 4.6.5. Disposal and Life-End Issues
 - 4.6.6. Operations Management



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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

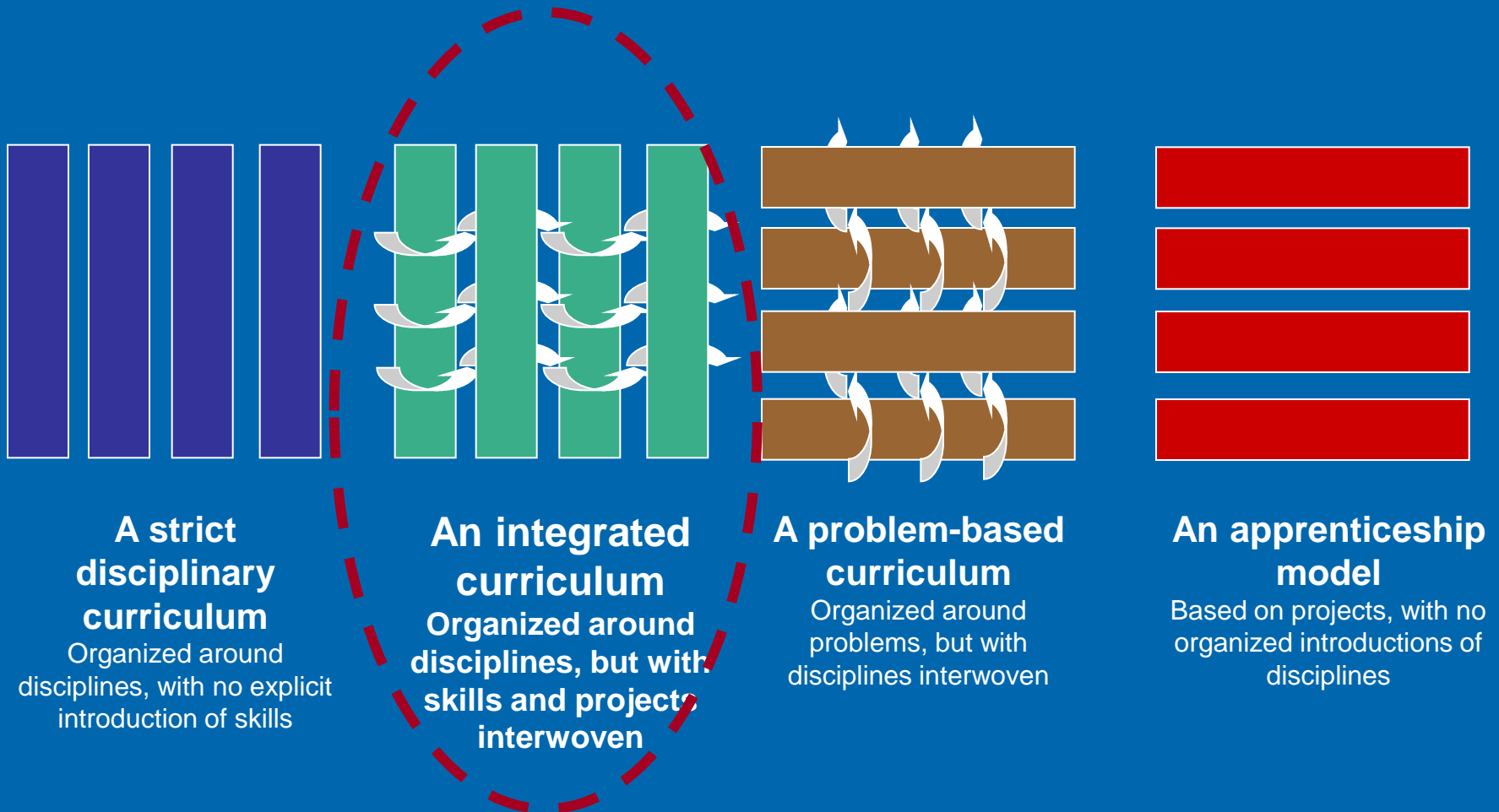


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(Disciplines run vertically; projects and skills run horizontally.)



SEQUENCING ENGINEERING SKILLS



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INTEGRATION OF SKILLS

Year 1	Introductory course	Physics	Mathematics I	
	Mechanics I	Mathematics II	Numerical Methods	
Year 2	Mechanics II	Solid Mechanics	Product development	
	Thermodynamics	Mathematics III	Fluid mechanics	Sound and Vibrations
Year 3	Control Theory	Electrical Eng.	Statistics	Signal analysis
	Oral communication	Written communication	Project management	Teamwork

(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



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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



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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)



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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 the same time as engineering principles and theory



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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



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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

CDIO Standard 12 -- Program Evaluation

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



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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



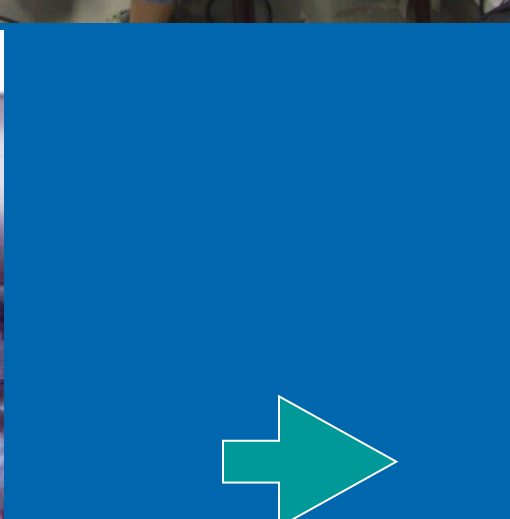
Interaction between
students' groups

Interaction
between
Students and
teachers



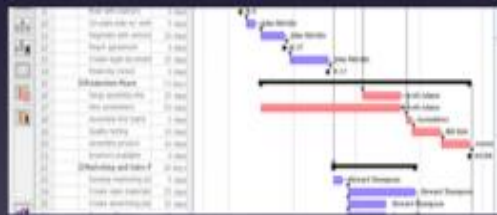
Teachers' team
work

Peer
discussion



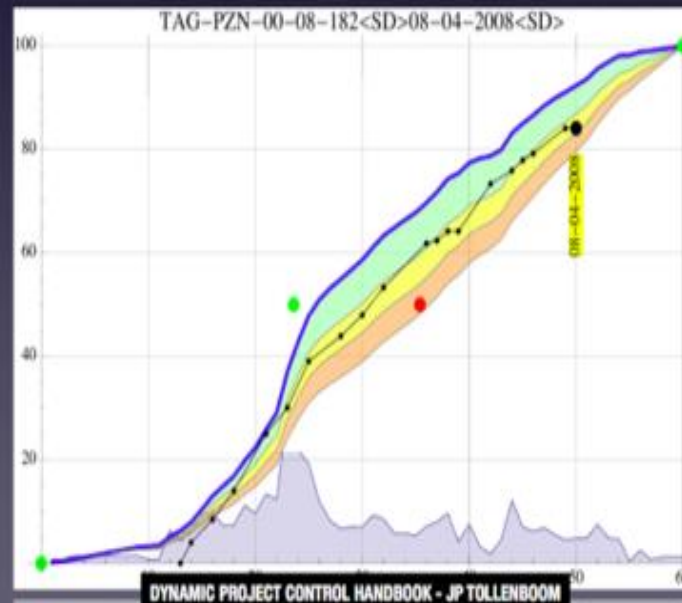
Learning process management

- Process control by Dynamic Project Control Tool
- Quality control
- Assessment of students performance



Task	Start	End	Duration	Progress
2018-01-01	2018-01-01	2018-01-01	1	100%
2018-01-02	2018-01-02	2018-01-02	1	100%
2018-01-03	2018-01-03	2018-01-03	1	100%
2018-01-04	2018-01-04	2018-01-04	1	100%
2018-01-05	2018-01-05	2018-01-05	1	100%
2018-01-06	2018-01-06	2018-01-06	1	100%
2018-01-07	2018-01-07	2018-01-07	1	100%
2018-01-08	2018-01-08	2018-01-08	1	100%
2018-01-09	2018-01-09	2018-01-09	1	100%
2018-01-10	2018-01-10	2018-01-10	1	100%

Task	Start	End	Duration	Progress
2018-01-01	2018-01-01	2018-01-01	1	100%
2018-01-02	2018-01-02	2018-01-02	1	100%
2018-01-03	2018-01-03	2018-01-03	1	100%
2018-01-04	2018-01-04	2018-01-04	1	100%
2018-01-05	2018-01-05	2018-01-05	1	100%
2018-01-06	2018-01-06	2018-01-06	1	100%
2018-01-07	2018-01-07	2018-01-07	1	100%
2018-01-08	2018-01-08	2018-01-08	1	100%
2018-01-09	2018-01-09	2018-01-09	1	100%
2018-01-10	2018-01-10	2018-01-10	1	100%



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.



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Peer instruction



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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



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Policy Briefing by The UNESCO Chair

ICTs FOR NEW ENGINEERING EDUCATION

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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.