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between Higher Engineering
Education and Industries

Reform Strategies for Professional Education and CDIO Model of Innovative Context for Cultivating Engineers

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Engineering Education Workshop

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Outline

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- Generalized “Vocational Education” (GVE) and its macro-control model
- Shortage of professional talents
- Proposed Paradigm for Profession Education
- CDIO – a new model for pedagogic process

What is GVE？

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✓All profession education, which directly supplies all levels of talents to meet the needs of society and industries

✓All profession education targeting graduates' ability/attributes/knowledge/skills for job market

✓All profession education providing different types of talents for national strategies to develop and construct social and economic strength

Professions: Engineering/technology, Medicine, Law, Accounting, Agriculture, Architecture, Secretariat ,……

✓Common characters of GVE:

- To meet professional requirements (quality, quantity, variety, levels);
- Forward-looking to future HR market;
- Unified profession and academic discipline (profession-based);
- Integrated theoretical and practical learning;
- Balanced hard and soft skills
- To cultivate graduates for competence and compatibility

GVE – Job-Oriented Education

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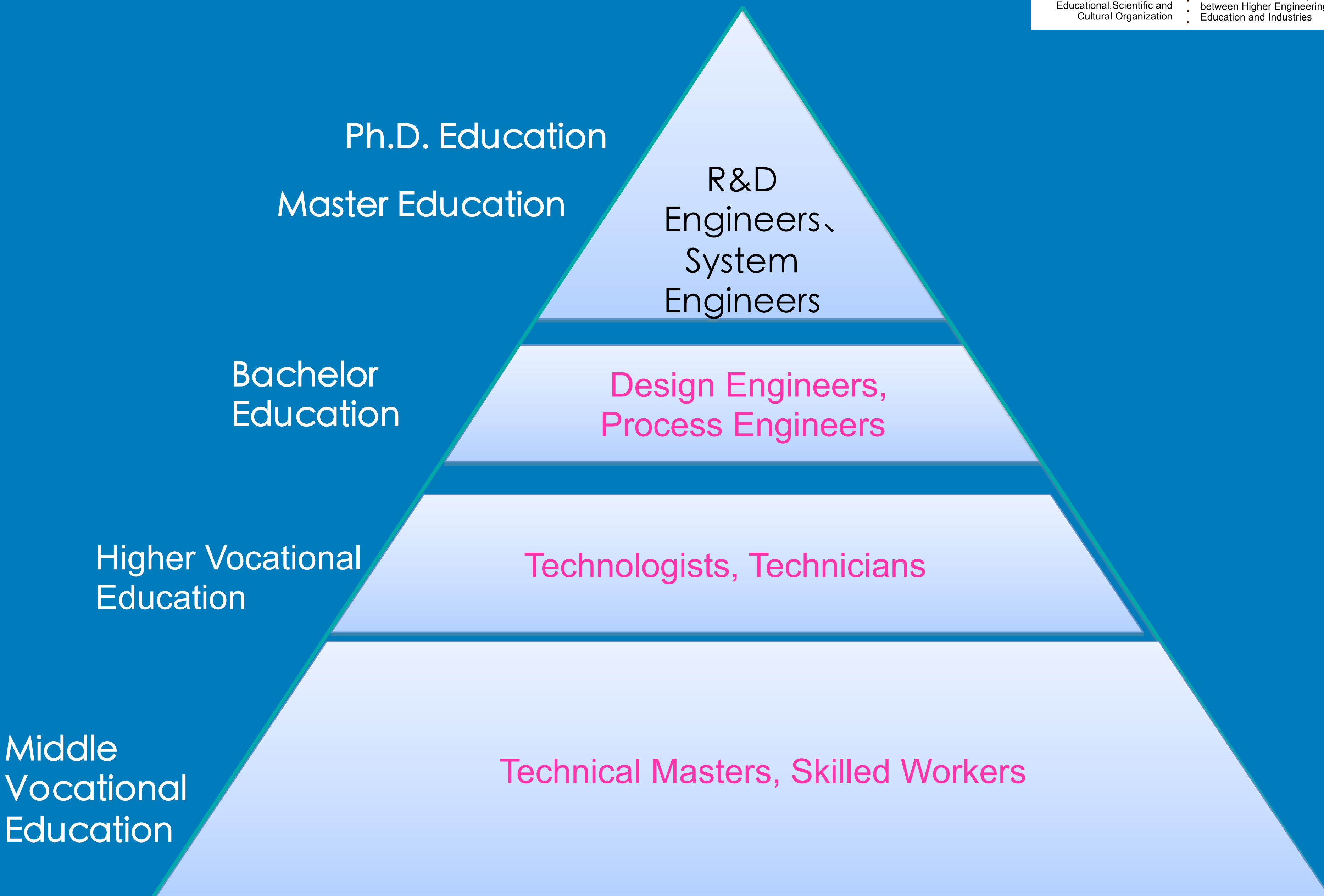

National Higher Vocational Education Institution
National Moscow Bauman University of Technology
National Research University of Technology and Processes

Future Development of GVE

Russia has categorized all profession education at all levels as Vocational Education (GVE)

Education Ministry：136 off total 541 universities will be closed due to too low quality and efficiency

UNESCO has defined Vocational & Technical Education) as a kind of education to meet requirements of professionals in job market, which includes middle/higher vocational education up to Ph.D. education

Macro Control Model for GVE

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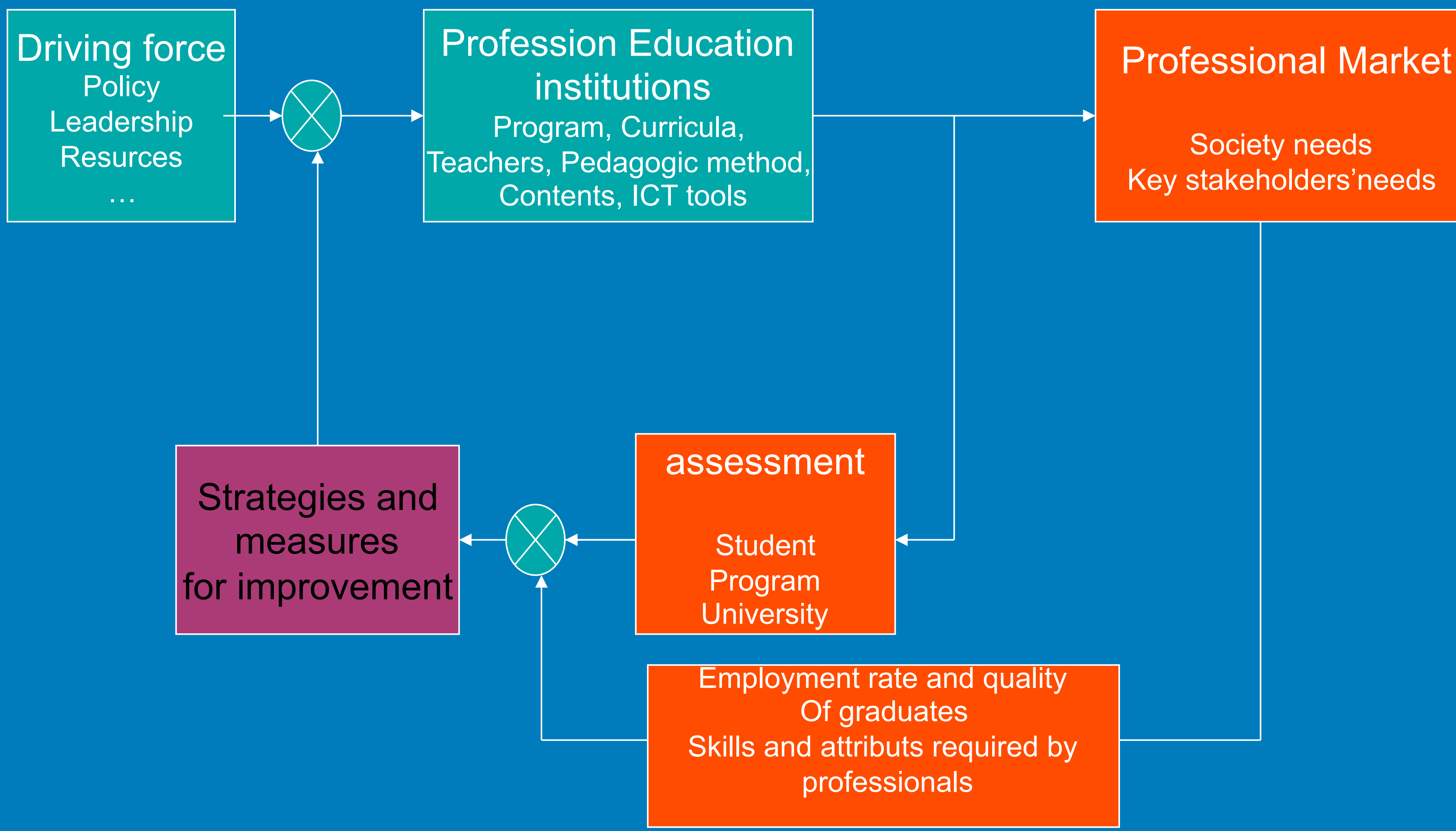

The goal of GVE

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（1） To satisfy needs of students on jobs – Career-oriented education

making students more competitive in world job market

(2) To meet the requirement of industry on talents – Cradle of Engineers

Providing graduates with abilities according to standard of engineering profession

（3) To meet strategic target of the government to build an innovative society

cultivating large qty. innovative graduates

Talents needed in quantity

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in China:

- multi-nation companies (280k, 3% of total) need 750k high quality graduates (60% of total available); Other 40% of graduates for domestic companies (97% of total)
- short of 3m IT talents in next 3 years, but only 500K graduates from colleges

For the past 3 years, IT related programs in colleges were among 10 highest unemployment rate for new graduates

At B.S. level

- Computer science and engineering （2） Red warning

At Diploma level (higher vocational education)

- Applied computer technology （1） Red warning
- E- commerce （3） Red Warning

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Talents needed in quantity

in Europe: short of 2.5 million engineering related professionals for next 5 years

in USA, workforce for science and engineering increased 1.5 times in 20 years, but enrollment of engineering study for citizen and PR decreased by 20%

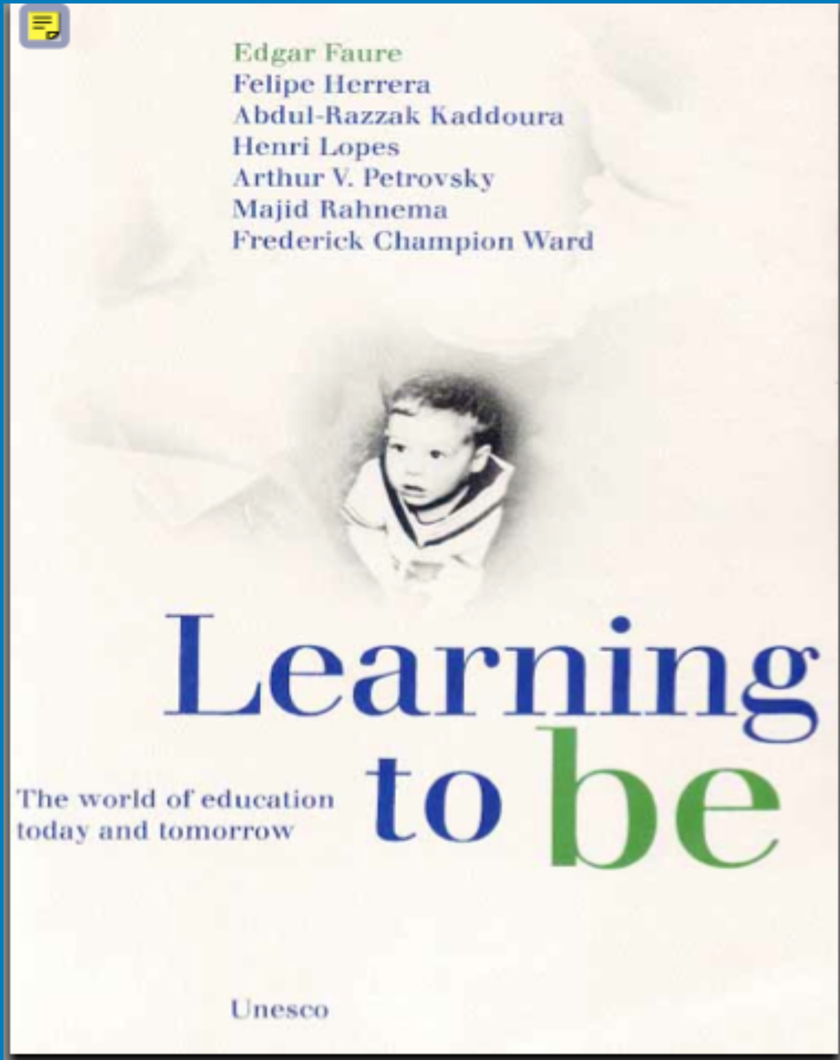
Same phenomena in Japan, South Korea and many others

Worldwide shortage of quality engineering talents

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



- Dr.William A. Wulf, the former president of National Academy of Engineering of USA, said, “Our society is dependent upon technology created by engineers. Engineering is changing rapidly, and I believe engineering education has to change even faster for us to maintain our quality of life.”

WilliamA.Wulf, “An Urgent Need for Change,”
http://www.tbp.org/pages/publications/Bent/Features/Sp04Wulf.pdf

Huge Gap between Context of Engineering Profession and Engineering Education

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

2. Mechanism: Isolated environment from industry

3. Faculties: weak engineer’s experiences and pedagogic training

4. Teaching method: Textbook-based instruction vs. Learning by Doing

5. Assessment: Close-book theoretical exams. Vs. Whole Learning Process Evaluation

Paradigm for Engineering Education

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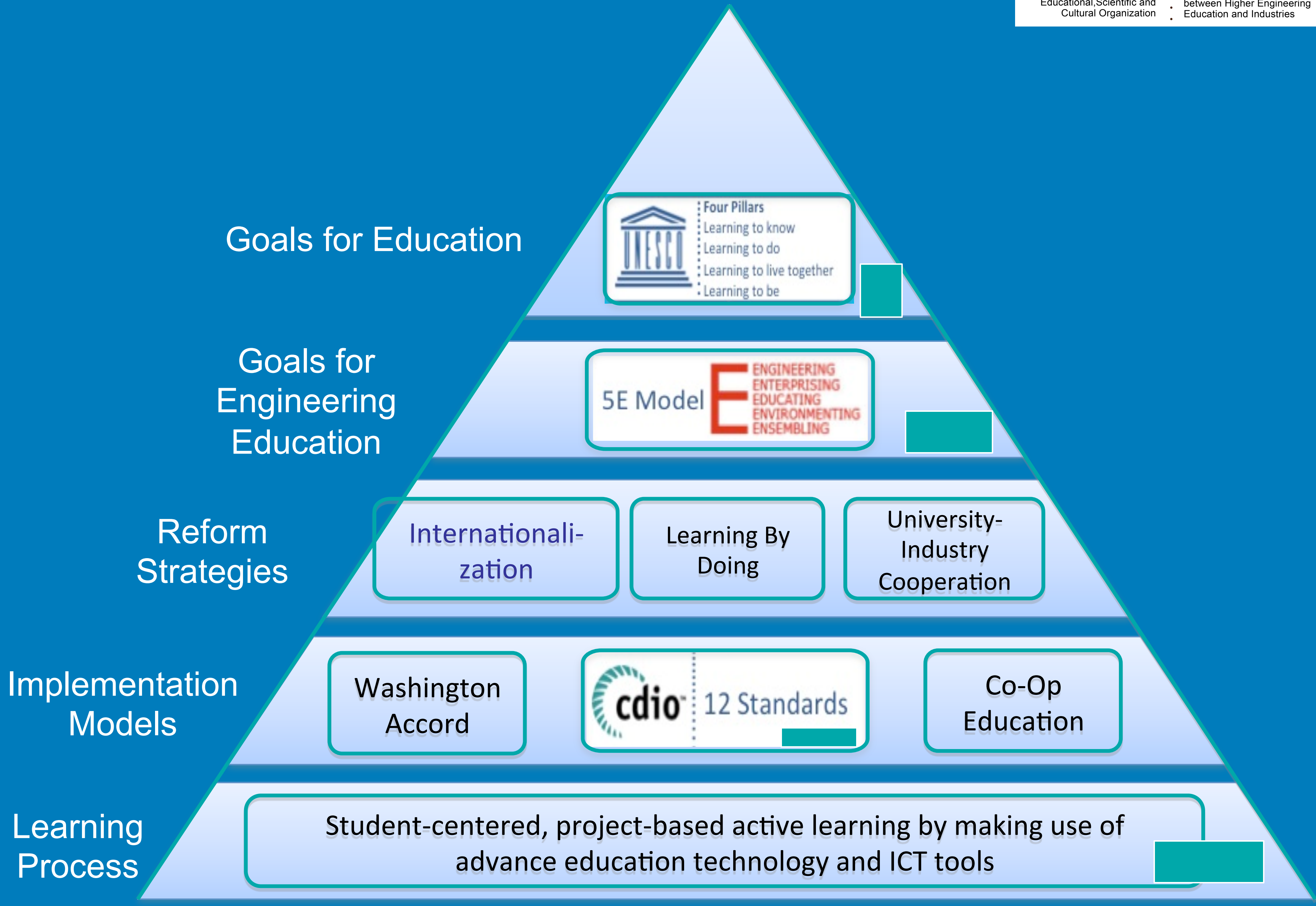

Best Practice of Engineering Education

- Co-Op Education Program in 1500 univ./college in 43 countries： University of Waterloo of Canada

- 200K college students join Co-Op program under support of 120K companies in USA

- 109 Demonstrative Higher Vocational Tech. Colleges succeed in China

- 37 Demonstrative Software Engineering Schools succeed, become cradle of competitive software engineers

"If we teach today as we taught yesterday, we rob our children of tomorrow

—John Dewey

We must continuously improve the engineering education!

Thank you for your attention!

Q&A

THE RETURN ON INVESTMENT

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

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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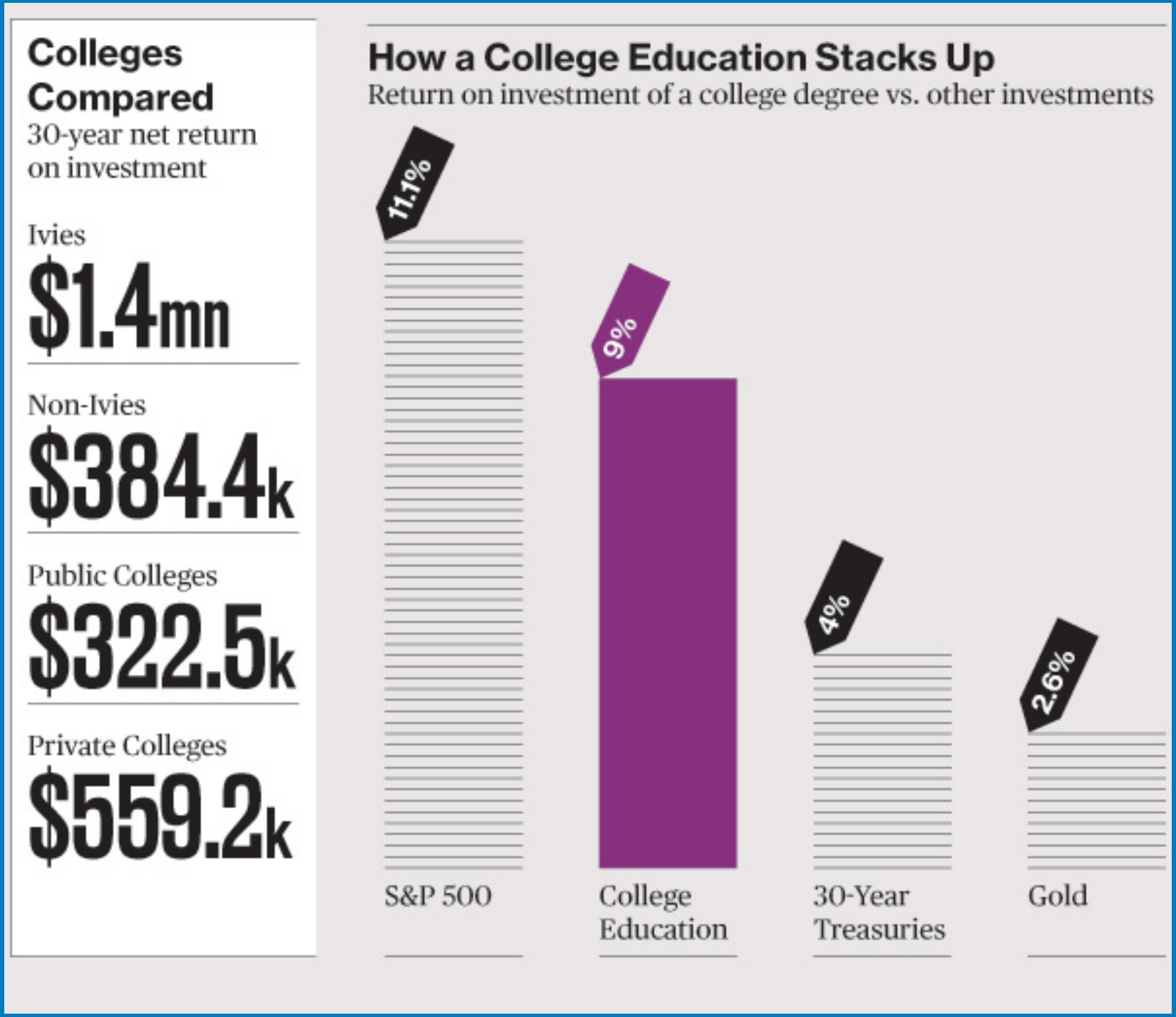

Reference: Louis Lavelle. College Degrees Get an Audit. Bloomberg Businessweek, June 28 –July 4, 2010, P15.

Desired attributes of an engineer
source: Boeing Management Company

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- 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

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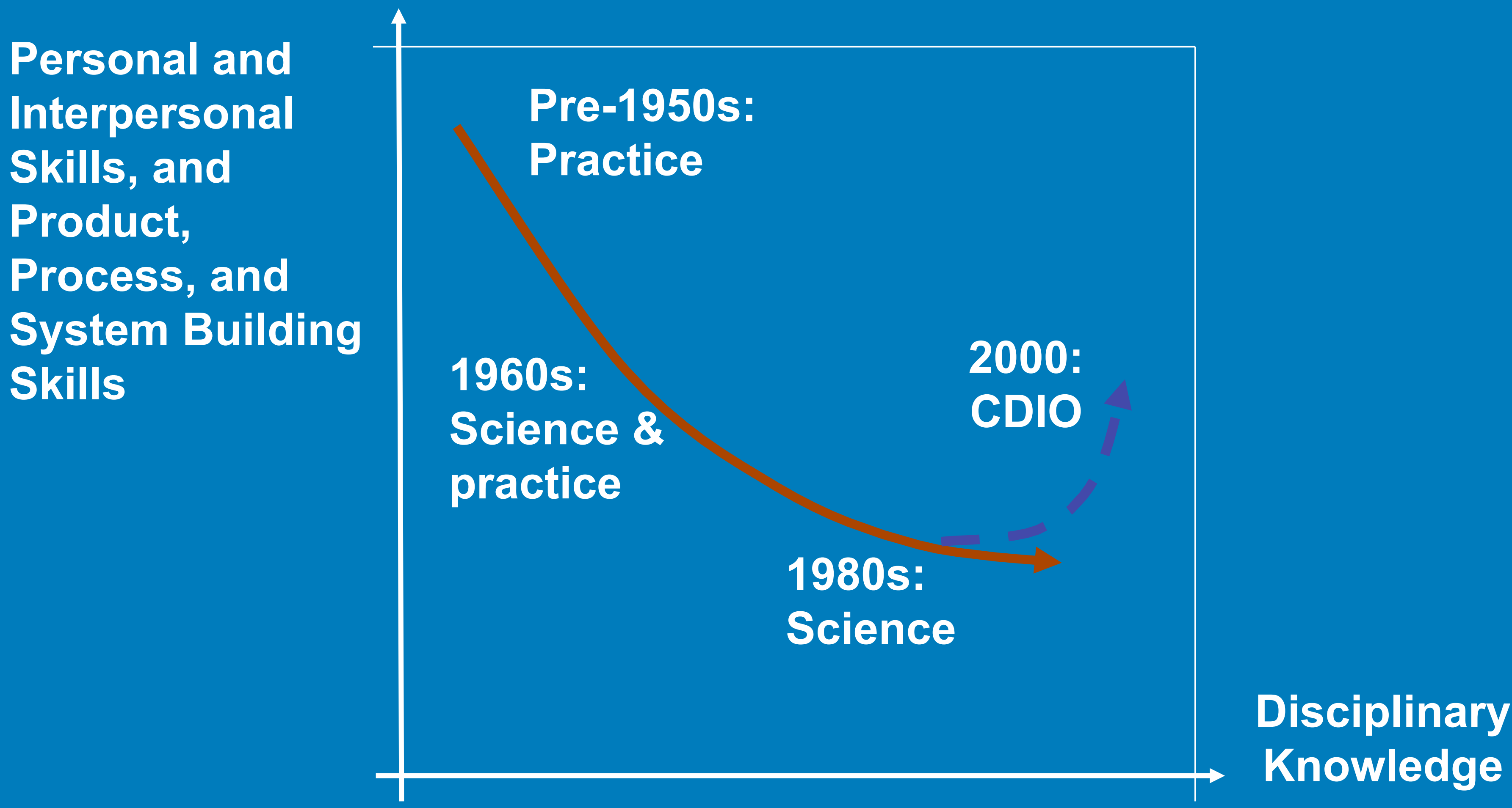
Student Resource for Engineering Education

- 2006: 70k engineers from USA, 700k from China
- China: Enrollment for engineering study
  800k college students
  1 million students of higher vocational institutes
- Percentage of engineering study in higher education
  China>35%
  Japan<20%, Germany<15%, UK<8%, USA<6%

NATIONAL DEVELOPMENT OF ENGINEERING EDUCATION



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

Strategy 2: Internationalization

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- Making use of the best student resources and education facilities for global engineering talent market
- Core: to cultivate talents by international standard

  RMIT：Fostering global citizen and professionals, globally employable

  India：350K/year engineers enter global market, will be 1.4 million/per year from 2015 on (Tony Blair)
- Leaders and teachers with global vision, capacity and strategy (Group T）
- Globalized university-industry cooperation：RMIT, WPI）

- International exchange and cooperation, (Shanghai Jiaotong U./ U.of Michigan)
- Student mobility: building up on-campus international environment to accommodate foreign students

USA: 40% of graduate students from abroad；

Oxford: 25% of students from 130 countries；

Tokyo Univ.： 2000 foreign students from 60 countries；

Group T： 15% of students from abroad

Native students will be most benefited by multi-cultural environment on campus too!

Strategy 1 ： Univ.- Industry Coop

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1.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 cont.

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

- CDIO：a systematic & complete model of PbL
- CDIO (Conceive,Design,Implement,Operate) : represents lifecycle of engineering project (product, process, system, and service)

CDIO APPROACH, STRUCTURE AND RESOURCES

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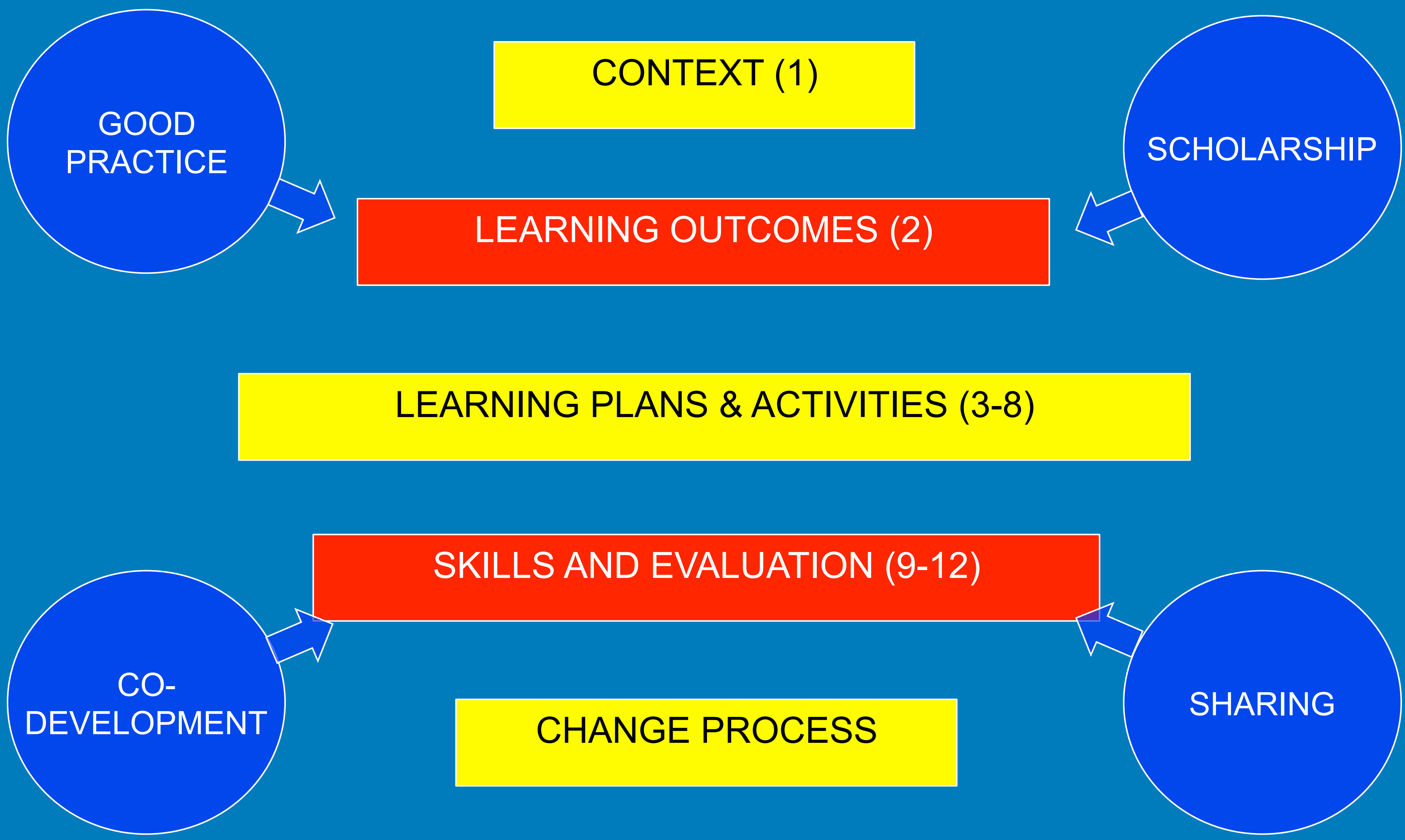

CDIO Standard 1 -- The Context

Adoption of the principle that product, process, and system lifecycle development and deployment – *CDIO*

- are the context for engineering education

- It's what engineers do for their profession!
- Provides the framework for teaching skills
- Allows deeper learning of the fundamentals
- Helps to attract, motivate, and retain students

What should be the context of engineering education? - the product/process/system lifecycle

- A focus on the needs of the customer
- Delivery of products, services and systems
- Incorporation of new inventions and technologies
- A focus on the solution, not disciplines
- Working with others, and within resources

CDIO Standard 2 -- Learning Outcomes

Specific, detailed learning outcomes for engineering professional skills, and 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(28 items for teamwork ability)
- 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

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

CDIO Standard 4 – Introduction to Engineering

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

- To motivate students to study engineering
- To provide early exposure to system building
- To teach some early and essential skills (*e.g.*, teamwork)
- To provide a set of personal experiences which will allow early fundamentals to be more deeply understood
- To build structure of knowledge

CDIO Standard 5 –
Design-Implement Experiences

A curriculum that includes two or more design-implement experiences

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 labs that support and encourage hands-on learning of engineering projects, disciplinary knowledge, and social learning

- Students are directly engaged in their own learning
- Settings with ICT tools 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 engineering practice skills

. To make dual use of student learning time

. Faculty serve as role models of engineers with practice skills and engineering principles in the same time

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

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CDIO Standard 9 – Enhancement of Faculty Skills Competence *

Actions that enhance faculty competence in engineering practice

- 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

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To enhance faculty competence in pedagogy background (integrated learning experiences, project-based active learning , and assessing student learning)

- Hire faculty with interest in education
- 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
- 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

CDIO Standard 12 -- Program Evaluation

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A system that evaluates programs against these twelve standards, and provides feedback to students, faculty, and other stakeholders for the purposes of continuous improvement

. Evidence-based evaluation and involving all 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）

Goals for learning: UNESCO Four Pillars

- Learn to Know
- Learn to Do
- Learn to Live together
- Learn to Be

5E Engineering Education Model

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- Engineering: Innovation – to design and make
- Enterprising: Entrepreneurship – vision, mission, deliver to market, cost effective, team work
- Educating: Developing ones- Life-long learning and to communicate with others
- Environmenting: Consciousness-adapting to multi-cultural and natural environment
- Ensembling: Responsibility-to be harmonic with society and nature, social and professional

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College students
learn from a pupil

Interaction between
students' groups

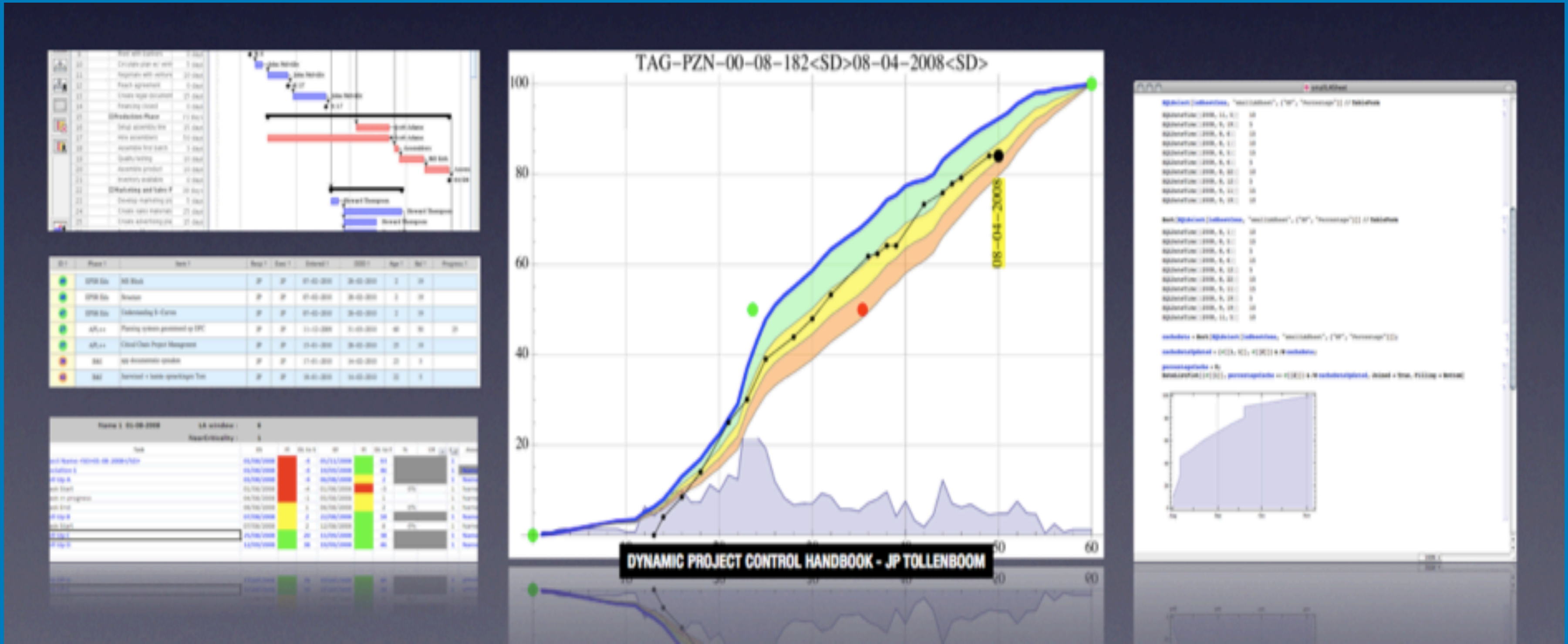
Teachers' team work

Interaction between
Students and teachers

Peer discussion

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

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- Internet based survey system with very high response rate (50%)
- Questionnairs 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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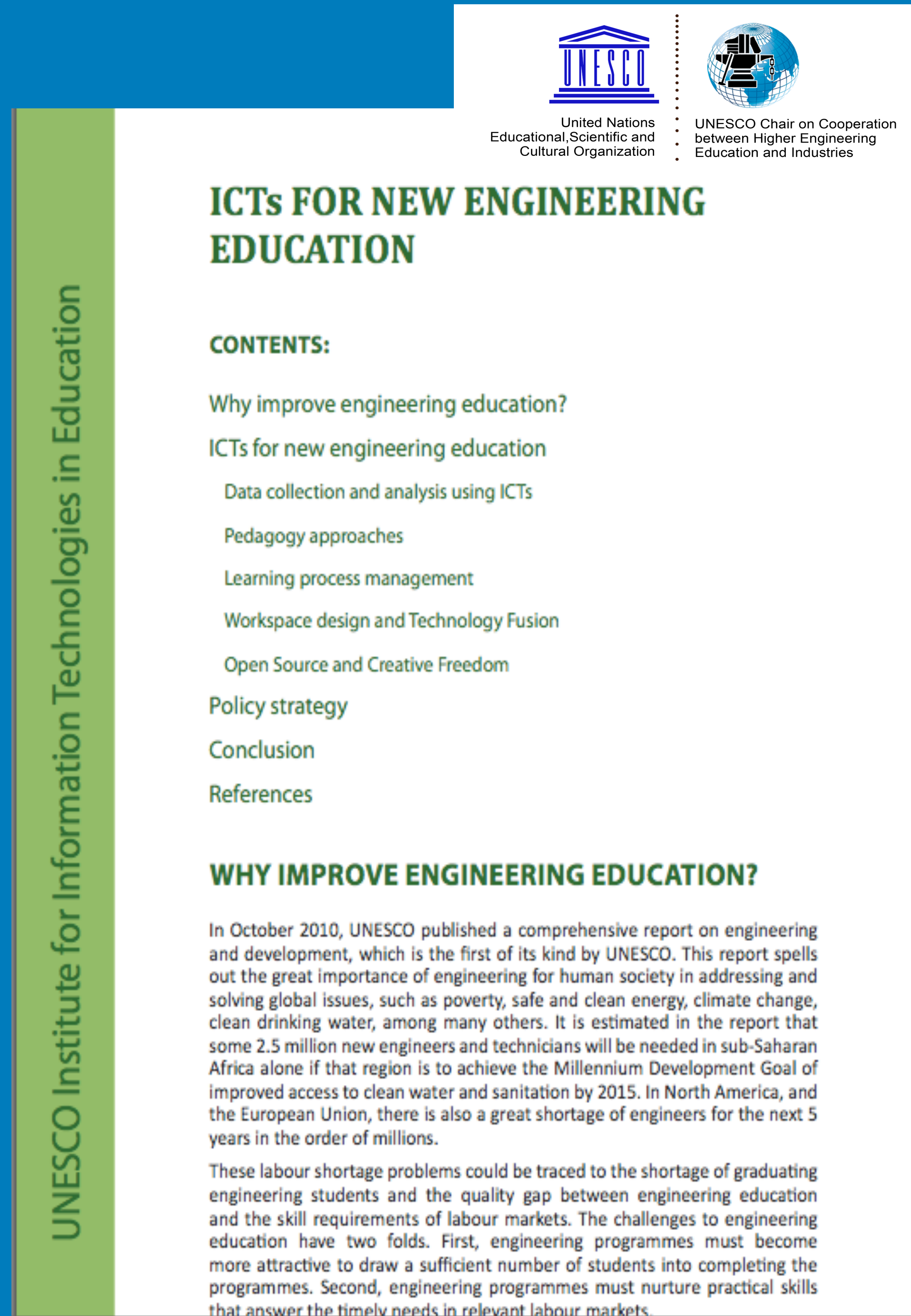
来源：**Prof. Alexander Khoroshilov, National Programme Officer/ Capacity Development Team Leader， UNESCO IITE**

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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ICTs FOR NEW ENGINEERING EDUCATION

CONTENTS:

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.