Sustaining educational change –

The case of a strategic and long-term CDIO implementation at Chalmers University of Technology

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SESSION OBJECTIVES

Recognize key factors that influence change in an organization

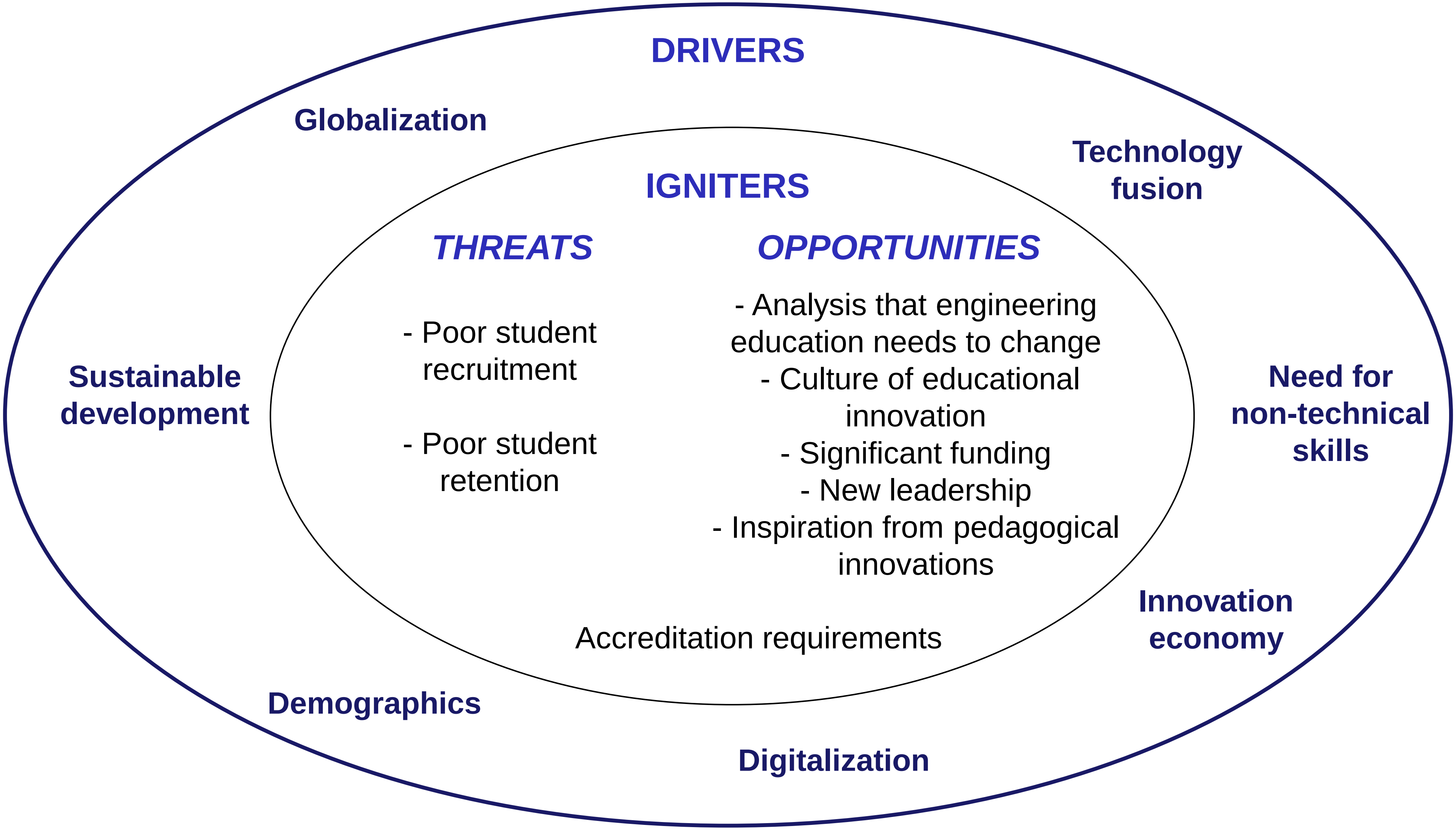
Examine the implementation process in a selected CDIO program

Discuss how to sustain educational development beyond the first project phase and identify supporting CDIO resources

OUTLINE

- Change driver and barriers in universities
- Generic change process model, adapted to education change
- Case: Mechanical engineering at Chalmers University of Technology
- CDIO implementation support and resources
- Concluding remarks & discussion

DRIVERS AND IGNITERS FOR EDUCATIONAL CHANGE



Based on R Graham: Achieving excellence in engineering education: the ingredients of successful change, 2012

BARRIERS TO CHANGE IN UNIVERSITY EDUCATION

"It has already been tried and it didn't work"

"We don't have time"

"Good idea, but the curriculum is already over-stuffed"

"I'll change but only if there is scientific evidence for the new approach"

"We don't have money"

"Our program is already good"

"Yes, we should do that but I don't have the competence"

"I need to focus on grants and research to get tenure/promotion"

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CHANGE IN UNIVERSITIES (CONT)

- Perspective 1: Universities are, by design, resistant to change as organizations
  - In Europe, of the more than 25 institutions that have operated continuously since the Reformation, all but four are universities

- Perspective 2: Notwithstanding Observation 1, universities can be changed by appropriate application of best practice in leading organizational change

KOTTER'S MODEL FOR ORGANIZATIONAL CHANGE PROCESSES

1 Establish a sense of urgency

2 Form a powerful guiding coalition

3 Create a vision

4 Communicate the vision

5 Empower others to act on the vision

6 Plan for and create short-term wins

7 Consolidate improvements and produce still more change

8 Institutionalize new approaches

ADAPTING KOTTER'S MODEL TO EDUCATIONAL DEVELOPMENT

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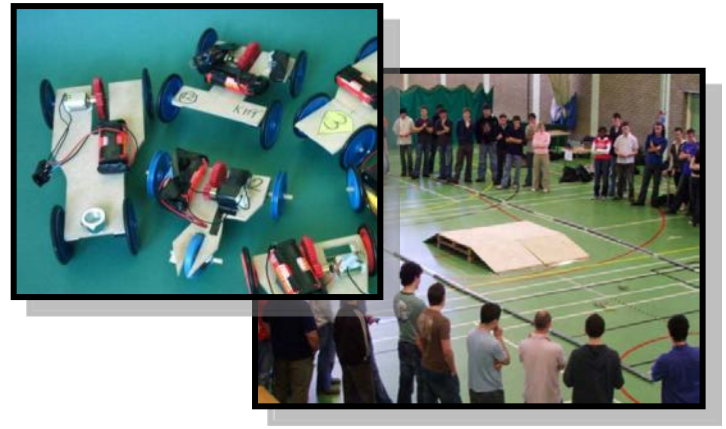
Getting off to the right start	Building the momentum in the core activities of the change	Institutionalizing change
1 Understanding the need for change 2 Leadership from the top 3 Creating a vision 4 Support for early adopters 5 Early successes	6 Moving off assumptions 7 Including students as agents of change 8 Involvement and ownership 9 Adequate resources	10 Faculty recognition and incentives 11 Faculty learning culture 12 Student expectations & academic requirements

EXAMPLES:
#5 EARLY SUCCESSES

- Identify and enhance CDIO syllabus learning outcomes for some courses
- Start, or modify, a first-year engineering course that includes a simple design-implement experience.
- Get involved in a student design-build competition like Formula Student
- Modify an existing classroom space to create a design-implement workspace that supports hands-on and social learning.

Teamwork?
Oral communication?



EXAMPLES:
#11 FACULTY LEARNING CULTURE

Enhancement of CDIO 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

EXAMPLES:
#11 FACULTY LEARNING CULTURE

Enhancement of Teaching Skills

- 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

PLANNING THE CHANGE PROCESS

- Evaluate your program. What are your strengths and weaknesses with respect to the CDIO Syllabus and Standards? **(1. Understand need)**

- Elaborate the vision and strategy – be ready to answer the why, what and how

- Identify some early successes **(5. Early Successes)**
  - Easy to implement
  - Quick payoff
  - Visible results

- Generate buy-in from faculty **(8. Involvement and Ownership)**
  - Give them tools and resources to help with changes
  - Reward faculty who embrace and drive CDIO
  - Give faculty ownership in the project

- Identify resources you need to before you embark on large changes – especially project-based courses **(9. Adequate resources)**

- Plan how to assess and measure the impact of the changes that you make

DISCUSSION

Turn to the person sitting next to you and discuss:

- What are the three most urgent needs for change in your program?
- What will you gain if you are able to address these needs?

THE CHANGE PROCESS OF
THE MECHANICAL ENGINEERING PROGRAMME AT
CHALMERS UNIVERSITY OF TECHNOLOGY

CASE STUDY: CHALMERS MECHANICAL ENGINEERING PROGRAM

- Five-year program leading to ”civilingenjör” degree (master of science in engineering)
- Organized in 3+2 format – students also obtain bachelor of science and master of science degrees
- 14 electable master programs, all taught in English
- 150 students admitted per year, 20% female
- Highest number of 1st pref application of Swedish mechanical engineering programs
- Appointed Centre of Excellence in Higher Education in 2008
- Awarded engineering education of the year award in 2012
- Awarded rating “very high quality” by Swedish National Agency of Higher Education (2013) (only ME program in Sweden with this rating)

UTMÄRKELSEN FRAMSTÅENDE UTBILDNINGSMILJÖ 2008 HÖGSKOLEVERKET

Centre of Excellence in Higher Education

HÖGSKOLEVERKET
Swedish National Agency for Higher Education

ÅRETS TEKNIK UTBILDNING 2012

PLANNING THE CHANGE AT CHALMERS

Identify needs & opportunities for change	***Strengths*** - Project-based courses - Design courses + More ***Weaknesses*** - No design-build-test projects, lack of authenticity - Employer requested better communication skills, project leadership & initiative - Poor links between maths and engineering subjects + More
Establish vision & strategy	CDIO was selected as basis for a program vision & strategy
Identify early successes	4th year design-build-test competition-based projects were focused (Formula Student, Autonomous vehicles)
Set up system for measuring the change	Self-assessment vs CDIO standards (but first we needed to articulate the standards and their rubrics) Invited external evaluators
Obtain management support & resources	Strong support from school leadership Financial support from Wallenberg foundation

VISION

The ”Civilingenjör” (MScEng) program in Mechanical Engineering aims to develop the knowledge, skills and attitudes that are needed to be able to

Lead and participate in the design and operation of industrial products, processes and systems

This includes the entire lifecycle from identifying needs, creating solutions, design, manufacturing, marketing, operating, maintaining, recycling to eliminating

PROGRAM STRATEGY (EXCERPT)

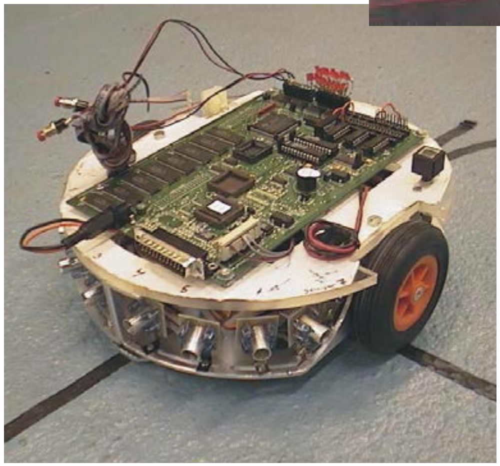
- The “main thread” of the programme is a holistic view of product and system lifecycle development and deployment.
- The programme should have computation-oriented and integrated mathematics education with focus on modelling, simulation and analyses
- The programme should have introductory provides a framework for the practice of engineering in product and system building and includes a
- Team-based DBT courses with realistic and relevant assignments should be included in all years
- The programme should have its own prototype laboratory and workshop, and adequate spaces for teamwork in projects
- Development of students´ teamwork and communication skills should be integrated in many courses with explicit progression
- Relevant aspects of sustainable development should be emphasized, and the focus is on product development, materials and energy supply
- **… (continued) …**

EARLY SUCCESSES

Formula Student

Autonomous vehicles

Visible, competition-based projects marketed the change project and communicated the idea of what the project was about to students and faculty



FROM THE STARTING POINTS - THE CDIO JOURNEY HAS TAKEN 10+ YEARS

Pre CDIO	CDIO planning	CDIO basic design & piloting	CDIO implementation	CDIO +
-2000	2000-2001	2001-2004	2004-2008	2009-
M2000 reform • Project courses • More design • Early eng experiences • Master-like profiles • No design-build-test	• Set project goals • Concretize CDIO concept • Bench-marking • Design-build-test pilots	• Prototyping lab • Multiple design-build-test projects • Integrated learning • 3+2 education structure adapted	• Mathematics • Sustainability • Bachelor project • English on master level • HSV Excellence center	• Virtual learning environment for math stat • Integrated sustainability • Set new goals • Visiting committee

INTEGRATED CURRICULUM YEAR 1-3

Year 1

Intro Mathematics 7.5 ECTS	Single-variable Calculus 7.5 ECTS	Linear Algebra 7.5 ECTS	Several-variable Calculus 7.5 ECTS
Programming in Matlab 4.5 ECTS	CAD M 4,5 hp	Mechanics and Solid Mechanics I 7.5 ECTS	Mechanics and Solid Mechanics I I 7.5 ECTS
Intro to Mechanical Eng 7.5 ECTS			

Year 2

Mechanics and Solid Mechanics I II 7.5 ECTS	Machine Elements 7.5 ECTS	Integrated Design and Manufacturing Project 7.5 ECTS	
Materials 7.5 ECTS	Materials and Manufacturing Technology 7.5 ECTS	Sustainable product development 4.5 ECTS	Industrial Production & Org 6 ECTS
		Thermodynamics 7.5 ECTS	Industrial Economics 4 ECTS

Year 3

Mechatronics 7.5 ECTS	Control Engineering 7.5 ECTS	Bachelor Thesis Project 15 ECTS	
Fluid Mechanics7.5 ECTS	Elective I 7.5 ECTS	Elective II 7.5 ECTS	Mathematical Statistics 7.5 ECTS

Common computation labs in mathematics, programming & engineering science

Communications

Teamwork

Sustainability

Integrative project in design & manufacturing

A CURRICULUM WITH MANY DESIGN-BUILD-TEST PROJECTS

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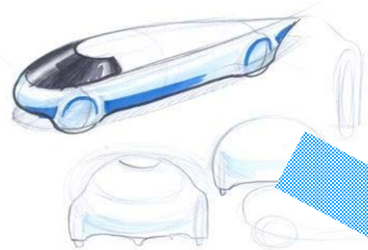
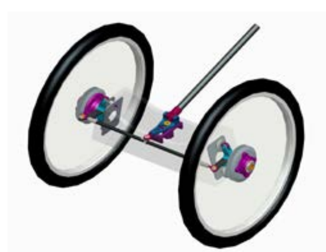
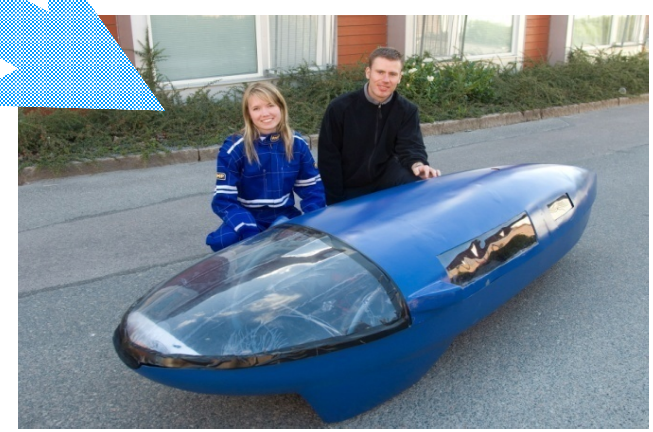
Year 1	Year 2	Year 3	Year 4
Intro to Mech Eng	Joint project in Machine elements & Manuf technology courses	Machine design	Mechatronics project course Automotive eng project Product development project
Creative, ”conceptual” design	Design for manufacturing	Redesign Multiple objectives	Creative design incl business aspects Cross-dept teams
Simple prototype Qualitative	More advanced prototype Some simulation Company is customer	Prototype as needed More simulation	Prototype Simulation as needed Company is customer

ADVANCED DESIGN-IMPLEMENT-TEST PROJECT



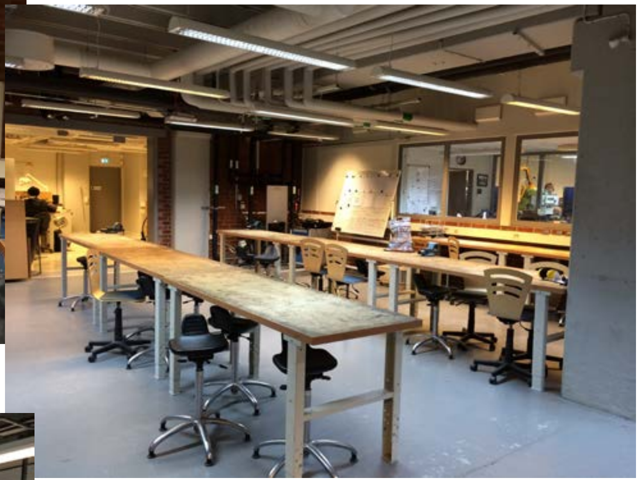
Chalmers EcoMarathon 2006

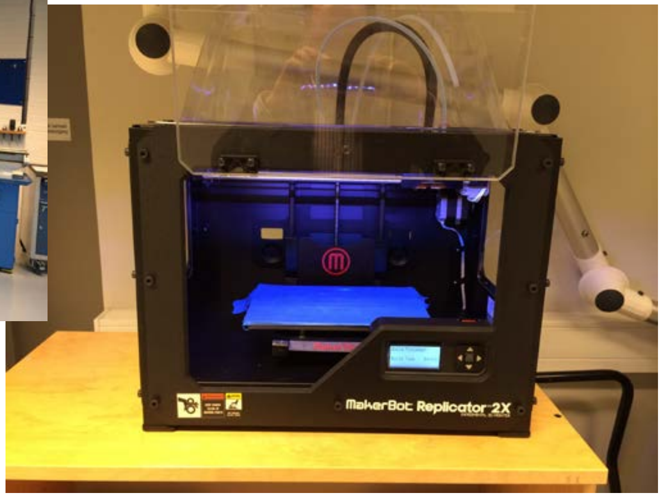




CDIO IMPLEMENTATION WORKSPACE – THE PROTOTYPING LABORATORY

- 450 m2 facility where students can build prototypes
- Metal machining, woodworking, rapid prototyping, welding, electronics, …
- Used in courses and projects from year 1 to master thesis projects





MATHEMATICS REFORM

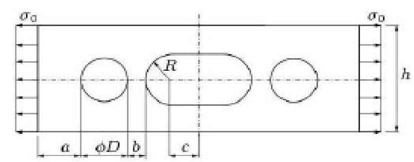
- Reformed mathematics emphasizing simulations
- Motivate importance of mathematics and applied mechanics courses
- Realistic engineering problems

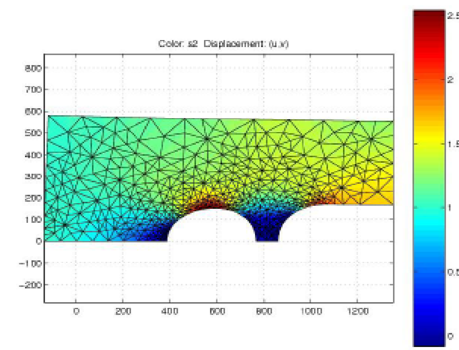
- Working method based on modelling, simulation & analysis
- MATLAB programming
- Visualization of mechanical behaviour

Year 1 lab example

Analys av plan elastiska skiva med fyra hål

Beräkna spänningskoncentrationsfaktorn. Avgör om spänningshöjningarna vid hålen samverkar. Symmetrier skall utnyttjas.





MEASURING THE CHANGE - SELF-ASSESSMENT WRT CDIO STANDARDS

Scale	Criteria
5	Evidence related to the standard is regularly reviewed and used to make improvements.
4	There is documented evidence of the full implementation and impact of the standard across program components and constituents.
3	Implementation of the plan to address the standard is underway across the program components and constituents.
2	There is a plan in place to address the standard.
1	There is an awareness of need to adopt the standard and a process in place to address it.
0	There is no documented plan or activity related to the standard.

CDIO STANDARD	EVIDENCE OF COMPLIANCE	RATING	ACTIONS
CDIO as Context Adoption of the principle that product and system lifecycle development and deployment – Conceiving, Designing, Implementing and Operating - are the context for engineering education			
CDIO Syllabus Outcomes Specific, detailed learning outcomes for personal, interpersonal and product and system building skills, consistent with program goals and validated by program stakeholders			
Integrated Curriculum A curriculum designed with mutually supporting disciplinary subjects, with an explicit plan to integrate personal, interpersonal and product and system building skills			
Introduction to Engineering An introductory course that provides the framework for engineering practice in product and system building, and introduces essential personal and interpersonal skills			

CDIO SELF-EVALUATION EVOLUTION

Standard		2000	2003	2005	2008	2010
1	CDIO as context	2	2	4	4	4
2	CDIO syllabus outcomes	1	1	2	4	4
3	Integrated curriculum	2	2	3	4	4
4	Integration to engineering	3	4	4	4	4
5	Design-build experiences	1	3	4	4	4
6	CDIO workspaces	1	3	4	4	4
7	Integrated learning experiences	2	2	3	4	4
8	Active learning	1	1	3	3	4
9	Enhancement of faculty CDIO skills	1	1	2	2	2
10	Enhancement of faculty teaching skills	1	2	2	3	3
11	CDIO skills assessment	2	2	3	3	3
12	CDIO programme evaluation	1	2	3	4	4
Average		1.5	2.1	3.1	3.6	3.7

0	1	2	3	4

CURRENT AND FUTURE PLANS

Short term	Long term
2010-2011	2010-2020
• Intellectual prop mgmt • Extended sustainability • Virtual learning environment in 1st year math courses • Material science courses with product focus • Expanded CAD course • Establish international visiting committee	• Interactive T, L & A • Dialogue instead of monologue • Creative abilities, innovation and entrepreneurship • New technologies and materials • Prepare for global collaboration and competition • Challenge-based innovation

LESSONS LEARNED FROM IMPLEMENTATION 1(2)

- Education reform needs to take place at least program level – not all pieces of CDIO are new, it is the comprehensiveness that makes the difference
- Education reform is not only about one radical change project, it also requires long-term continuous improvement
- The standards and the benchmarking methods developed in the CDIO project helped structure and continuously improve the program
- The ME program has come out positively in several evaluations due to its CDIO implementation
- Industry has been very positive throughout
- The CDIO project has strengthened the teacher team

LESSONS LEARNED FROM IMPLEMENTATION 2(2)

- As a first visible effect, the creation of a few design-build projects at an early stage was a showcase for the project

- Some tasks took much longer time than expected
  - Building the prototyping lab & reforming the mathematics course
  - Continual support from management and program advisory board is needed

- We still only have few individuals who can take responsibility for professional and non-technical skills
  - Vulnerability - faculty development important

PAIR-WISE DISCUSSION: CHALLENGES

Turn to the person sitting next to you and discuss:

- Identify 3 key challenges or barriers that you face in implementing a CDIO approach in your program.
- What resources can you draw on to address these challenges?

CONCLUDING REMARKS: SUSTAINED EDUCATIONAL DEVELOPMENT

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Getting off to the right start	Building the momentum in the core activities of the change	Institutionalizing change
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\+ But more is needed!

BUT MORE IS NEEDED

- High ambitions and goals
- A customized approach that fits the needs and constraints of the program
- A program-level perspective
- An ability to set new goals
- A challenging program advisory board or visit committee
- Long-term strategy & vision, continuity
- Active search for external input
- An effective quality enhancement system
- Development and maintenance of a teacher team with a program perspective
- A continual effort to create attention to educational issues

Based on R Graham: Achieving excellence in engineering education: the ingredients of successful change, 2012

TO LEARN MORE ABOUT CDIO …

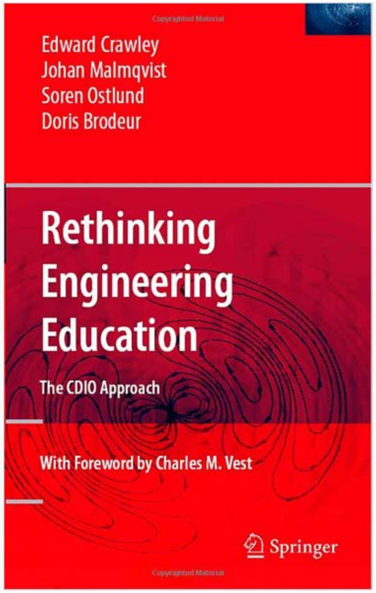
OPEN-SOURCE RESOURCES

Available at http://www.cdio.org

- The CDIO Syllabus
- The CDIO Standards
- Start-Up Guidance
- Implementation Kit (I-Kit)
- Papers from CDIO conferences

Other

- *Rethinking Engineering Education: The CDIO Approach* by Crawley, Malmqvist, Östlund, & Brodeur, 2007
- Annual international CDIO conference
- Local, regional, and international workshops



Thank you for listening!

Any questions or comments?