Re-engineering Engineering curricula for sustainability development

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Several factors have open up for improvements towards SD in education at KTH

- Bologna process: 3+2 year curricula (B.Sc/M.Sc) from fall 2007 → Programs are changed!
- New national directive for higher education is pushing
- New national validation criteria to meet (incl. SD)
- Pull from students and society
- Ongoing Pedagogical revolution: "From teaching to learning"
The Strategic issue: Society needs a new kind of engineer!

Old focus:
- Context: Engineering + science (classic)
- Reduced, “pure” problems (with right and wrong answers)
- Design phase
- Individual effort

Desired focus:
- Context: Product and system development (products and systems in a wide sense including generic and contextual SD)
- Systems view, problems go across disciplines, are complex and ill-defined, and contain environmental, societal and business aspects
- Understand the whole cycle: Conceive, design, implement, operate (www.CDIO.org)
- Teamwork, communication
The Strategic issue: Society needs a new kind of engineer!

Present focus
- Context: Engineering + Science (classic)
- Reduced, “pure” problems (with right and wrong answers)
- Design phase
- Individual effort

Desired focus
- Context: product and system development (products and systems in a wide sense including generic and contextual SD)
- Systems view, problems go across disciplines, are complex and ill-defined, and contain environmental, societal and business aspects
- Understand the whole cycle: Conceive, Design, Implement, Operate (www.CDIO.org)
- Teamwork, communication
A modern (engineering) curricula must therefore address a long list of desired competences:

1. Scientific (math, physics etc)
2. Technical (engineering science)
3. Communication skills
4. Project/leadership skills
5. SD, i.e understand engineering systems in the societal, environmental and business context
6. Entrepreneurship
7. Innovation etc, etc…

These competences (3-7) **may** be given in separate course modules making up programs to B.Sc or M.Sc levels…
A modern (engineering) curricula must therefore address a long list of desired competences:

1. Scientific (math, physics etc)
2. Technical (engineering science)
3. Communication skills
4. Project/leadership skills
5. Sustainable development in engineering, i.e. understand engineering systems in the societal, environmental and business context
6. Entrepreneurship
7. etc, etc…

These competences (3-7) may be given in separate course modules making up programs to B.Sc or M.Sc levels.
The pedagogic challenge: Systematic integration of competencies

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Development routes (schematic)
Integration of SD at course level in all engineering curricula at ITM/KTH (2008-present)

Q: Why integration of SD in courses?

A: Students need *motivation* and *context* so learn engineering skills (and SD).

A: It leads to teacher involvement in SD issues

A: previous experiences from dedicated courses dealing with environmental issues (etc) has not been encouraging
How to do it?

Method: Develop contextual (intended) learning outcomes (LO) for SD explicit for all relevant courses in programs

Process: Benchmarking SD today →negotiating and setting new program goals →developing LO’s →course mapping and development → implementation → follow up →”Green program awards”? 
What is a learning outcome?

- Skills, Techniques, Working knowledge, etc. that the student acquires during a course or a program
- It should be expressed explicitly: “…on completion of the course the students shall be able to solve…”
- Expressed using Bloom (or other) taxonomies
- LO’s will be treated as generic or contextual…
Chosen structure to classify and select aspects of SD in educational programs

Understand ozone hole mechanism?
Sustainable development is context-dependent and should be learned and assessed in the (appropriate) technical/scientific context.

Understand ozone hole mechanism
Integration of SD competencies into:

1. Objectives
2. Activities
3. Assessment

Program goals in SD

2. Intended Learning outcomes
   What should the student be able to do with respect to SD as a result of the particular course?

3. Designing activities
   What work is appropriate for the student to do to reach the intended LO’s?

4. Designing assessment
   What should the student do to demonstrate that they reached the intended LO’s?

So-called Constructive Alignment must be used*)

*)Biggs 1999
The basic idea: Systematic integration of competencies

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Black box coordination exercise (finetuning)

INPUT:

Previous knowledge and skills

OUTPUT:

Input to later course i
Input to later course ii
Input to later course iii etc.
Final competence

- All courses in the program are presented through their input-output only
- The black box approach enables efficient discussions
- Makes connections visible (as well as lack thereof !)
- Serves as a basis for improving coordination between courses
- Helps faculty learn about the program as a whole
Typical project (messy, x-disciplinary, ill-defined problem)

**Sust. Energy systems for remote Islands**
Economical, Physical and Social constraints.
Start in modeling of energy demand based on desired activities
Real climatic data
Build as sustainable as possible within given constraints (CO2/cost)
Build model
The implementation process

1. Benchmarking:
   - Review of program goals
   - Negotiating new program goals to include SD
   - Strategy documents
   - Review existing LO’s for courses
   - Self evaluation
   - Identification of contextual examples of LO’s within each program
Starting point I: Existing curriculum (self evaluation)

What SD competences (generic and contextual) are already addressed in program courses?

- The existing curriculum is *benchmarked* through self assessment + expert team
- The "program owners" are asked to select examples of *contextual SD issues*
- Follow up *interviews* with faculty members responsible for a specific course in the program
Starting point II: Program planning/Validation

What SD competencies (and other competences expressed through the CDIO Syllabus) should be prioritized in this program?

- Validate plans with all stakeholders
- Setting program goals in SD
- This is made through surveys to alumni, students, industry
- Comparisons with accreditation / regulations etc
- Discussions by faculty
Process overview

1a. Validation with stakeholders

1b. Benchmarking of existing courses (interviews) and self-assessment

2. Mapping of SD and other skills such as entrepreneurship to existing and new courses

3. Course development

4. Fine-tune coordination