CDIO INTRODUCTORY WORKSHOP

HANDBOOK

Materials to Supplement Slides

Revised January 2008

THE CDIO STANDARDS

Background

A major international project to reform undergraduate engineering education was launched in October 2000. This project, called *The CDIO Initiative*, has expanded to include engineering programs worldwide. The vision of the project is to provide students with an education that stresses engineering fundamentals set in the context of Conceiving--Designing--Implementing--Operating (CDIO) real-world systems and products. The *CDIO Initiative* has three overall goals - to educate students who are able to:

- master a deep working knowledge of technical fundamentals
- lead in the creation and operation of new products and systems
- understand the importance and strategic impact of research and technological development on society

The *CDIO Initiative* creates resources that can be adapted and implemented by individual programs to meet these goals. These resources support a curriculum organized around mutually supporting disciplines, interwoven with learning experiences related to personal and interpersonal skills, and product, process, and system building skills. Students receive an education rich in design-implement experiences and active and experiential learning, set in both the classroom and modern learning workspaces. One of these resources, the CDIO Standards, is provided in this document. For more information about the *CDIO Initiative*, visit http://www.cdio.org

The CDIO Standards

In January 2004, the *CDIO Initiative* adopted 12 standards that describe CDIO programs. These guiding principles were developed in response to program leaders, alumni, and industrial partners who wanted to know how they would recognize CDIO programs and their graduates. As a result, these CDIO Standards define the distinguishing features of a CDIO program, serve as guidelines for educational program reform and evaluation, create benchmarks and goals with worldwide application, and provide a framework for continuous improvement.

The 12 CDIO Standards address program philosophy (Standard 1), curriculum development (Standards 2, 3 and 4), design-implement experiences and workspaces (Standards 5 and 6), new methods of teaching and learning (Standards 7 and 8), faculty development (Standards 9 and 10), and assessment and evaluation (Standards 11 and 12). Of these 12 standards, seven are considered *essential* because they distinguish CDIO programs from other educational reform initiatives. (An asterisk [*] indicates these essential standards.) The five *supplementary* standards significantly enrich a CDIO program and reflect best practice in engineering education.

For each standard, the *description* explains the meaning of the standard, the *rationale* highlights reasons for setting the standard, and *evidence* gives examples of documentation and events that demonstrate compliance with the standard.

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

Description: A CDIO program is based on the principle that product, process, and system lifecycle development and deployment are the appropriate context for engineering education. *Conceiving--Designing--Implementing--Operating* is a model of the entire product, process, and system lifecycle. The *Conceive* stage includes defining customer needs; considering technology, enterprise strategy, and regulations; and, developing conceptual, technical, and business plans. The second stage, *Design*, focuses on creating the design, *i.e.*, the plans, drawings, and algorithms that describe what will be implemented. The *Implement* stage refers to the transformation of the design into the product, process, or system, including manufacturing, coding, testing and validation. The final stage, *Operate*, uses the implemented product or process to deliver the intended value, including maintaining, evolving and retiring the system.

The product, process, and system lifecycle is considered the *context* for engineering education in that it is the cultural framework, or environment, in which technical knowledge and other skills are taught, practiced and learned. The principle is *adopted* by a program when there is explicit agreement of faculty to transition to a CDIO program, and support from program leaders to sustain reform initiatives.

Rationale: Beginning engineers should be able to *Conceive--Design--Implement--Operate* complex value-added engineering products, processes, and systems in modern team-based environments. They should be able to participate in engineering processes, contribute to the development of engineering products, and do so while working in engineering organizations. This is the essence of the engineering profession.

Evidence:

- a mission statement, or other documentation approved by appropriate responsible bodies, that describes the program as being a CDIO program
- faculty and students who can explain the principle that the product, process, and system lifecycle is the context of engineering education

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

Description: The knowledge, skills, and attitudes intended as a result of engineering education, *i.e.,* the *learning outcomes*, are codified in the *CDIO Syllabus*. These learning outcomes detail what students should know and be able to do at the conclusion of their engineering programs. In addition to learning outcomes for technical disciplinary knowledge (Section 1), the *CDIO Syllabus* specifies learning outcomes as personal and interpersonal skills, and product, process, and system building. *Personal* learning outcomes (Section 2) focus on individual students' cognitive and affective development, for example, engineering reasoning and problem solving, experimentation and knowledge discovery, system thinking, creative thinking, critical thinking, and professional ethics. *Interpersonal* learning outcomes (Section 3) focus on individual and group interactions, such as, teamwork, leadership, and communication. *Product, process, and system building* skills (Section 4) focus on conceiving, designing, implementing, and operating systems in enterprise, business, and societal contexts.

Learning outcomes are reviewed and validated by key *stakeholders*, groups who share an interest in the graduates of engineering programs, for consistency with *program goals* and relevance to engineering practice. In addition, stakeholders help to determine the expected level of proficiency, or standard of achievement, for each learning outcome.

Rationale: Setting specific learning outcomes helps to ensure that students acquire the appropriate foundation for their future. Professional engineering organizations and industry representatives have identified key attributes of beginning engineers both in technical and professional areas. Moreover, many evaluation and accreditation bodies expect engineering programs to identify program outcomes in terms of their graduates' knowledge, skills, and attitudes.

Evidence:

- learning outcomes that include knowledge, skills, and attitudes of graduating engineers
- learning outcomes validated for content and proficiency level by key stakeholders (for example, faculty, students, alumni, and industry representatives)

Standard 3 -- Integrated Curriculum *

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

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Description: An integrated curriculum includes learning experiences that lead to the acquisition of *personal and interpersonal skills, and product, process, and system building skills* (Standard 2), interwoven with the learning of disciplinary knowledge. Disciplinary courses are *mutually supporting* when they make explicit connections among related and supporting content and learning outcomes. An *explicit plan* identifies ways in which the integration of skills and multidisciplinary connections are to be made, for example, by mapping the specified learning outcomes to courses and co-curricular activities that make up the curriculum.

Rationale: The teaching of personal and interpersonal skills, and product, process, and system building skills should not be considered an addition to an already full curriculum, but an integral part of it. To reach the intended learning outcomes in disciplinary knowledge and skills, the curriculum and learning experiences have to make dual use of available time. Faculty play an active role in designing the integrated curriculum by suggesting appropriate disciplinary linkages, as well as opportunities to address specific skills in their respective teaching areas.

Evidence:

- a documented plan that integrates personal and interpersonal skills, and product, process, and system building skills with technical disciplinary skowledge, and that exploits appropriate disciplinary linkages
- inclusion of the specified skills in courses and co-curricular activities
- faculty and student recognition of these skills in the curriculum

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

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Description: The *introductory* course, usually one of the first required courses in a program, provides a framework for the practice of engineering. This *framework* is a broad outline of the tasks and responsibilities of an engineer, and the use of disciplinary knowledge in executing those tasks. Students engage in the *practice of engineering* through problem solving and simple design exercises, individually and in teams. The course also includes personal and interpersonal skills knowledge, skills, and attitudes that are *essential* at the start of a program to prepare students for more advanced product, process, and system building experiences. For example, students can participate in small team exercises to prepare them for larger development teams.

Rationale: Introductory courses aim to stimulate students' interest in, and strengthen their motivation for, the field of engineering by focusing on the application of relevant core engineering disciplines. Students usually elect engineering programs because they want to build things, and introductory courses can capitalize on this interest. In addition, introductory courses provide an early start to the development of the essential skills described in the *CDIO Syllabus*.

Evidence:

- 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

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

Description: The term *design-implement experience* denotes a range of engineering activities central to the process of developing new products and systems. Included are all of the activities described in Standard One at the *Design* and *Implement* stages, plus appropriate aspects of conceptual design from the *Conceive* stage. Students develop product, process, and system building skills, as well as the ability to apply engineering science, in design-implement experiences integrated into the curriculum. Design-implement experiences are considered *basic* or *advanced* in terms of their scope, complexity, and sequence in the program. For example, simpler products and systems are included earlier in the program, while more complex design-implement experiences appear in later courses designed to help students integrate knowledge and skills acquired in preceding courses and learning activities. Opportunities to conceive, design, implement, and operate products, processes, and systems may also be included in required co-curricular activities, for example, undergraduate research projects and internships.

Rationale: Design-implement experiences are structured and sequenced to promote early success in engineering practice. Iteration of design-implement experiences and increasing levels of design complexity reinforce students' understanding of the product, process, and system development process. Design-implement experiences also provide a solid foundation upon which to build deeper conceptual understanding of disciplinary skills. The emphasis on building products and implementing processes in real-world contexts gives students opportunities to make connections between the technical content they are learning and their professional and career interests.

Evidence:

- two or more required design-implement experiences in the curriculum (for example, as part of an introductory course and an advanced course)
- required co-curricular opportunities for design-implement experiences (such as, research labs or internships)
- concrete learning experiences that provide the foundation for subsequent learning of disciplinary skills

Standard 6 -- Engineering Workspaces

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

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Description: The physical learning environment includes traditional learning spaces, for example, classrooms, lecture halls, and seminar rooms, as well as engineering *workspaces* and *laboratories*. Workspaces and laboratories support the learning of *product, process, and system building skills* concurrently with *disciplinary knowledge*. They emphasize *hands-on learning* in which students are directly engaged in their own learning, and provide opportunities for *social learning*, that is, settings where students can learn from each other and interact with several groups. The creation of new workspaces, or remodeling of existing laboratories, will vary with the size of the program and resources of the institution.

Rationale: Workspaces and other learning environments that support hands-on learning are fundamental resources for learning to design, implement, and operate products, processes, and systems. Students who have access to modern engineering tools, software, and laboratories have opportunities to develop the knowledge, skills, and attitudes that support product, process, and system building competencies. These competencies are best developed in workspaces that are student-centered, user-friendly, accessible, and interactive.

Evidence:

- adequate spaces equipped with modern engineering tools
- workspaces that are student-centered, user-friendly, accessible, and interactive
- high levels of faculty, staff, and student satisfaction with the workspaces

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

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Description: Integrated learning experiences are pedagogical approaches that foster the learning of disciplinary knowledge simultaneously with personal and interpersonal skills, and product, process, and system building skills. They incorporate professional engineering issues in contexts where they coexist with disciplinary issues. For example, students might consider the analysis of a product, the design of the product, and the social responsibility of the designer of the product, all in one exercise. Industrial partners, alumni, and other key stakeholders are often helpful in providing examples of such exercises.

Rationale: The curriculum design and learning outcomes, prescribed in Standards 2 and 3 respectively, can be realized only if there are corresponding pedagogical approaches that make dual use of student learning time. Furthermore, it is important that students recognize engineering faculty as role models of professional engineers, instructing them in disciplinary knowledge, personal and interpersonal skills, and product, process, and system building skills. With integrated learning experiences, faculty can be more effective in helping students apply disciplinary knowledge to engineering practice and better prepare them to meet the demands of the engineering profession.

Evidence:

- integration of personal and interpersonal skills, and product, process, and system building skills, with disciplinary knowledge in learning activities and experiences
- direct involvement of engineering faculty in implementing integrated learning experiences
- involvement of industrial partners and other stakeholders in the design of learning experiences

Standard 8 -- Active Learning

Teaching and learning based on active experiential learning methods

Description: *Active learning* methods engage students directly in thinking and problem solving activities. There is less emphasis on passive transmission of information, and more on engaging students in manipulating, applying, analyzing, and evaluating ideas. Active learning in lecture-based courses can include such methods as partner and small-group discussions, demonstrations, debates, concept questions, and feedback from students about what they are learning. Active learning is considered *experiential* when students take on roles that simulate professional engineering practice, for example, design-implement projects, simulations, and case studies.

Rationale: By engaging students in thinking about concepts, particularly new ideas, and requiring some kind of overt response, students not only learn more, they recognize for themselves what and how they learn. This process of metacognition helps to increase students' motivation to achieve program learning outcomes and form habits of lifelong learning. With active learning methods, instructors can help students make connections among key concepts and facilitate the application of this knowledge to new settings.

Evidence:

- successful implementation of active learning methods, documented, for example, by observation or self-report
- a majority of instructors using active learning methods
- high levels of student achievement of all learning outcomes
- high levels of student satisfaction with learning methods

Standard 9 -- Enhancement of Faculty Skills Competence *

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

Description: CDIO programs provide support for faculty to improve their own competence in the *personal and interpersonal skills, and product, process, and system building skills* described in Standard 2. They develop these skills best in contexts of professional engineering practice.

The nature and scope of faculty development vary with the resources and intentions of different programs and institutions. Examples of *actions that enhance faculty competence* include: professional leave to work in industry, partnerships with industry colleagues in research and education projects, inclusion of engineering practice as a criterion for hiring and promotion, and appropriate professional development experiences at the university.

Rationale: If faculty are expected to teach a curriculum of personal and interpersonal skills, and product, process, and system building skills integrated with disciplinary knowledge, as described in Standards 3, 4, 5, and 7, they need to be competent in those skills themselves. Many engineering professors tend to be experts in the research and knowledge base of their respective disciplines, with only limited experience in the practice of engineering in business and industrial settings. Moreover, the rapid pace of technological innovation requires continuous updating of engineering skills. Faculty need to enhance their engineering knowledge and skills so that they can provide relevant examples to students and also serve as role models of contemporary engineers.

Evidence:

- majority of faculty with competence in personal and interpersonal skills, and product, process, and system building skills, demonstrated, for example, by observation and self-report
- high number of faculty with experience in engineering practice
- university's acceptance of professional development in these skills in its faculty evaluation and hiring policies and practices
- commitment of resources for faculty development in these skills

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

Description: A CDIO program provides support for faculty to improve their competence in *integrated learning experiences* (Standard 7), active and experiential learning (Standard 8), and assessing student learning (Standard 11). The nature and scope of faculty development practices will vary with programs and institutions. Examples of *actions that enhance faculty competence* include: support for faculty participation in university and external faculty development programs, forums for sharing ideas and best practices, and emphasis in performance reviews and hiring on effective teaching methods.

Rationale: If faculty members are expected to teach and assess in new ways, as described in Standards 7 8, and 11, they need opportunities to develop and improve these competencies. Many universities have faculty development programs and services that might be eager to collaborate with faculty in CDIO programs. In addition, if CDIO programs want to emphasize the importance of teaching, learning, and assessment, they must commit adequate resources for faculty development in these areas.

Evidence:

- majority of faculty with competence in teaching, learning, and assessment methods, demonstrated, for example, by observation and self-report
- university's acceptance of effective teaching in its faculty evaluation and hiring policies and practices
- commitment of resources for faculty development in these skills.

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

Description: Assessment of student learning is the measure of the extent to which each student achieves specified learning outcomes. Instructors usually conduct this assessment within their respective courses. Effective learning assessment uses a variety of methods matched appropriately to learning outcomes that address *disciplinary knowledge,* as well as *personal and interpersonal skills, and product, process, and system building skills*, as described in Standard 2. These methods may include written and oral tests, observations of student performance, rating scales, student reflections, journals, portfolios, and peer and self-assessment.

Rationale: If we value personal and interpersonal skills, and product, process, and system building skills, and incorporate them into curriculum and learning experiences, then we must have effective assessment processes for measuring them. Different categories of learning outcomes require different assessment methods. For example, learning outcomes related to *disciplinary knowledge* may be assessed with oral and written tests, while those related to design-implement skills may be better measured with recorded observations. Using a variety of assessment methods accommodates a broader range of learning styles, and increases the reliability and validity of the assessment data. As a result, determinations of students' achievement of the intended learning outcomes can be made with greater confidence.

Evidence:

- assessment methods matched appropriately to all learning outcomes
- successful implementation of assessment methods
- high number of instructors using appropriate assessment methods
- determination of student achievement based on reliable and valid data

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

Description: *Program evaluation* is a judgment of the overall value of a program based on evidence of a program's progress toward attaining its goals. A CDIO program should be evaluated relative to *these 12 CDIO Standards*. Evidence of overall program value can be collected with course evaluations, instructor reflections, entry and exit interviews, reports of external reviewers, and follow-up studies with graduates and employers. The evidence can be regularly reported back to instructors, students, program administrators, alumni, and other key stakeholders. This *feedback* forms the basis of decisions about the program and its plans for *continuous improvement*.

Rationale: A key function of program evaluation is to determine the program's effectiveness and efficiency in reaching its intended goals. Evidence collected during the program evaluation process also serves as the basis of continuous program improvement. For example, if in an exit interview, a majority of students reported that they were not able to meet some specific learning outcome, a plan could be initiated to identify root causes and implement changes. Moreover, many external evaluators and accreditation bodies require regular and consistent program evaluation.

Evidence:

- 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

The CDIO Syllabus (Condensed)

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 OneÕs 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 OneÕs 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. COMMUNICATIONS IN FOREIGN LANGUAGES
  - 3.3.1. English
  - 3.3.2. Languages of Regional Industrial Nations
  - 3.3.3. Other Languages

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. SocietyÕs 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

Massachusetts Institute of Technology

Department of Aeronautics and Astronautics

Program Educational Objectives and Outcomes

Department Mission

The mission of the Department of Aeronautics and Astronautics is to prepare engineers for success and leadership in the conception, design, implementation, and operation of aerospace and related engineering systems. This is achieved through a commitment to educational excellence; to the creation, development, and application of the technologies critical to aerospace vehicle and information engineering; and to the architecture and engineering of complex high-performance systems.

Department Program Goals

The overall goals of the educational programs in the Department of Aeronautics and Astronautics are to educate students who are able to:

- Master a deep working knowledge of technical fundamentals
- Lead in the creation and operation of new products and systems
- Understand the importance and strategic impact of research and technological development in society

Program Objectives

Specifically, the programs in Aeronautics and Astronautics have these objectives:

1. Demonstrate a deep working knowledge of technical fundamentals
2. Conduct research, solve problems, think about systems, and master other personal and professional skills
3. Communicate effectively and work in multidisciplinary teams
4. Conceive, design, implement, and operate products, processes, and systems in enterprise and societal contexts.

Program Outcomes

The four program educational objectives are further specified as 16 program outcomes. These are measurable achievements that focus on what students know, are able to do, and/or have an opinion about as a result of Aeronautics and Astronautics programs. The 16 program outcomes are listed below as second-level items aligned with the four program objectives.

1.0 Demonstrate a deep working knowledge of technical fundamentals

- 1.1 Demonstrate a capacity to use the principles of the underlying sciences of mathematics, physics, chemistry, and biology
- 1.2 Apply the principles of core engineering fundamentals in fluid mechanics, solid mechanics and materials, dynamics, signals and systems, thermodynamics, control, computers and computation
- 1.3 Demonstrate deep working knowledge of professional engineering in aerodynamics, structural mechanics, structures and materials, jet and rocket propulsion, flight and advanced aerospace dynamics, computational techniques, estimation and

navigation, human and supervisory control, digital communication, software engineering, autonomy, and digital circuits and systems

2.0 Conduct research, solve problems, think about systems, and master other personal and professional attributes
  2.1 Analyze and solve engineering problems
  2.2 Conduct inquiry and experimentation in engineering problems
  2.3 Think holistically and systemically.
  2.4 Master personal skills that contribute to successful engineering practice: initiative, flexibility, creativity, curiosity, and time management
  2.5 Master professional skills that contribute to successful engineering practice: professional ethics, integrity, knowledge of contemporary issues, and lifelong learning

3.0 Communicate effectively and work in multidisciplinary teams
  3.1 Lead and work in teams
  3.2 Communicate effectively in writing, in electronic form, in graphic media, and in oral presentations

4.0 Conceive, design, implement, and operate products, processes, and systems in enterprise and societal contexts
  4.1 Recognize the importance of the societal context in engineering practice
  4.2 Appreciate different enterprise cultures and work successfully in organizations
  4.3 Conceive engineering systems including setting requirements, defining functions, modeling, and managing projects
  4.4 Design complex systems
  4.5 Implement hardware and software processes and manage implementation procedures.
  4.6 Operate complex systems and processes and manage operations

Chalmers University of Technology

Department of Product and Production Development

Master Programme: Industrial Design Engineering

Programme aim

The aim of the programme is that the students should develop enhanced knowledge, skills and abilities for industrial product development and design. The student should develop further theoretical as well as practical knowledge of methods and tools for innovative product development and design, and knowledge and skills to be able to develop and design innovative products and product systems taking different aspects into consideration including technical, human, and formal aspects.

Learning outcomes

The desired learning outcomes involve Knowledge and Understanding; Skills and abilities; and Formulation of judgement and attitudes.

Knowledge and understanding

The student should be able to

1. describe the scientific bases for areas of relevance for product development and industrial design engineering. This means to be able to:
   - 1.1. describe and assess different product development theories including theories on design work and design practice
   - 1.2. describe and reflect upon the state-of-the-art in product development research, including engineering design, industrial design, and human factors engineering
2. demonstrate a deeper knowledge and understanding of product development and industrial design engineering. This means to be able to:
   - 2.1. describe and assess different product development and design strategies
   - 2.2. describe and assess different methods, tools and techniques for conceiving, designing, and implementing product development and design solutions
   - 2.3. describe and reflect upon the role of processes, methods and tools for strategic, tactical and operative product development and design decisions

Abilities and skills

The students should be able to

3. demonstrate the knowledge, skills and ability to independently analyse, define and deal with a complex industrial design engineering problem. This means to be able to:
   - 3.1. collect and use the relevant information needed for solving an industrial design engineering problem
   - 3.2. choose and employ the relevant theories, methods and tools in different stages of the development process: for project planning; for idea generation and assessment; for concept development and assessment; as well as for detailed design
   - 3.3. create design solutions taking into consideration different aspects. This means to be able to:
     - 3.3.1. apply and integrate relevant theoretical knowledge in engineering design (mechanics, materials technology, and production technology), industrial design (basic design, aesthetics) and ergonomics/human factors to an industrial design engineering problem
     - 3.3.2. apply relevant theories, methods and tools in solving technical design problems
     - 3.3.3. apply relevant theories, methods and tools in solving formal design problems

        3.3.4. apply relevant theories, methods and tools in solving design problems concerning the interplay with ‘man and machine’
    3.4. critically and systematically handle and harmonise different types and (possibly) conflicting requirements
    3.5. critically assess, choose and justify design proposals from different perspectives (technical, human, social etc.).
4. efficiently and in a professional manner, communicate plans, results, thoughts and ideas to different target groups. This means to be able to
    4.1. communicate, orally and in writing, with experts as well as non-experts
    4.2. communicate, orally and in writing, in a national as well as in an international context
    4.3. choose and use different methods and tools for communication including computer-supported tools for visualisation
5. demonstrate skill and ability to work in teams
6. demonstrate skill and ability to co-operate in multidisciplinary and multicultural environments

Formulation of judgements and attitudes

The student should be able to

7. formulate judgements regarding technology and technical development that reflect scientific, social and ethical considerations
8. critically assess the possibilities and limitations of technology and technical development, its role in society, and its role in people’s everyday life
9. demonstrate awareness of the importance of developing further knowledge and increased competence

CDIO Benchmarking Survey Protocol

Survey Protocol

Have the following materials available for the interviews:

- Blank survey forms
- Sheet of "Explanations of Introduce, Teach, Utilize"
- Condensed version of the CDIO syllabus
- Full description of the topical CDIO syllabus
- One page summary of the CDIO project
- This protocol sheet

1. Introduce goal of the survey – to benchmark in which courses/subjects CDIO topics are currently deployed, so an effective re-design of the curriculum can take place.

2. Remind respondents of the background of the CDIO project (see attached page).

3. Explain definitions of I - *introduce,* T- *teach,* U- *utilize*. **It is allowable for one topic to receive both a T-*teach* and U-*utilize* for the same course/subject.**

4. Ask, "In relation to your subject, do you I - *introduce,* T- *teach,* U- *utilize* this topic (2.1)?" Ask, "Which sub-area(s) do you emphasize (2.1.1), (2.1.2), etc?" Repeat questions for 2.2, 2.3, 2.4, 2.5, 3.1, 3.2, 4.1, 4.2, 4.3, 4.4, 4.5

5. Ask, "If your answer was T- *teach* or U- *utilize*, which subjects, if any, provided the previous I – *introduction* or T- *teaching*?"

6. Ask, "If your answer was T-*teach*, which subjects, if any, will provide U-*utilization*?"

7. Ask, "Are there any additional comments you would like to make?"

8. Ask, "What is the name and number of the course/subject that you teach?"
   "How many times have you taught this course/subject?"
   "Is this a new course/subject, is the curriculum stable, or is it undergoing significant reform?"
   "How familiar are you with the CDIO curriculum?"
   "Do you have a statement of learning objectives for this course/subject?"

Explanations of *Introduce*, *Teach*, *Utilize*

Introduce:

- Touch on or briefly expose the students to this topic
- No specific learning objective of knowledge retention is linked to this topic
- Typically less than one hour of dedicated lecture/discussion/laboratory time is spent on this topic
- No assignments/exercises/projects/homework are specifically linked to this topic
- This topic would probably not be assessed on a test or other evaluation instrument

Example: At the beginning of class an example is given of the operation of an engineering system (4.6) to motivate an aspect of the design. But, no explicit discussion of the design or analysis of operation is presented.
Example: An ethical problem or dilemma (2.5) is presented to the students that sets the context for an example or lecture. But, no explicit treatment of ethics or its role in modern engineering practice is presented.

Teach:

- Really try to get students to learn new material
- Learning objective is to advance at least one cognitive level (e.g. no exposure to knowledge, knowledge to comprehension, comprehension to application, etc.)
- Typically, one or more hours of dedicated lecture/discussion/laboratory time are spent on this topic
- Assignments/exercises/projects/homework are specifically linked to this topic
- This topic would probably be assessed on a test or other evaluation instrument

Example: The process and methodology of product design (4.4) are explicitly presented to and practiced by the students on a project or assignment.
Example: Several workshops are presented on working in teams and group dynamics (3.1), and a coach works with students on understanding teamwork throughout the semester's team project.

Utilize:

- Assumes the student already has a certain level of proficiency in this topic
- No specific learning objective is linked to this topic, but the student will use knowledge of **this topic** to reach **other** learning objectives
- No time explicitly allotted to teaching this topic
- Assignments/exercises/projects/homework are not designed to explicitly teach this topic
- Tests or other evaluation instruments are not designed to explicitly assess this topic

Example: When teaching a topic other than communication, students are expected to utilize their skills in preparing oral presentations (3.2) which explain their work. But, no further explicit instruction in communications is given.
Example: When working in a laboratory session, students are expected to utilize their skills of experimentation (2.2). But, no further explicit instruction on techniques of experimentation are given.

Sample Interview Questions to Benchmark Curriculum and Instruction

Course______________________________ Instructor(s)______________________
Person Being Interviewed _____________________________
Interviewer ____ Date________________

- What is it you would most like to improve when it comes to the *quality of student learning* in this course?
- Describe what a student will be able to do after successful completion of this course (in terms of knowledge, skills, and attitudes)?
- What learning outcomes from The CDIO Syllabus are addressed in this course?
- What areas of knowledge from previous courses need to be improved?
- When do students get feedback during this course? How do they use the feedback?
- What are the *most* motivating aspects of the course to students?
- What are the *least* motivating aspects of the course to students?
- Describe the main tasks and roles of the instructor(s) in this course. What resources are available, and how are they used? Are the resources adequate or too demanding, as the course is organized today?
- What other comments would you like to make about teaching this course?

(Courtesy of Johan Malmqvist, Sören Östlund, and Kristina Edström)

INTEGRATED PROGRAM DESCRIPTIONS

An integrated program description (IPD) describes the goals, content and structure of an educational program, as well as how these are connected. The intent is to provide the program chair and other key stakeholders involved in the program design process with a set of tools that can facilitate their design process. It also deliberately promotes a design process which emphasizes high-level considerations such as setting goals and developing the program idea. This facilitates the alignment of the goals and content of the program with actual stakeholder needs, and may point out necessary major changes which can be very difficult to motivate and implement when applying the more common practice of program (re)design to modifying an existing program plan. An integrated program description contains six basic components:

The ***program purpose***, a high-level statement of why the program exists, which defines the overall purpose of the program, including its context and the future professional tasks and roles of its graduates. The program purpose at least defines the particular field that the program addresses (electrical, vehicle etc engineering), the relevant lifecycle phases (conceive, design, implement, …) and may imply a specific focus. For example, the program purpose of the Vehicle Engineering program at KTH states that

> *"The discipline of Vehicle Engineering includes aircraft, spacecraft, sea vessels, ground and track vehicles, and systems including such. The Vehicle Engineering program aims at giving the students knowledge, skills and attitudes required to conceive, design, implement and operate such vehicles and systems. The program also prepares the students for work in other fields where knowledge of applied mechanics and systems engineering is of importance, and for graduate studies."*

The ***program goals*** define the knowledge, skills and attributes that the graduates are expected to have developed upon graduation. The program goals can be described as a concretization of the program purpose into a set of assessable learning outcomes. For a CDIO program, the starting point is likely the CDIO Syllabus. However, items in the CDIO Syllabus need to be developed into learning outcomes by connected them to appropriate cognitive verbs, goals for disciplinary knowledge need to be stated and perhaps other adaptations made as well.

The ***program idea*** describes how the program is designed in order to meet its goals. It states the main principles and considerations that underlie the program design. Examples of (elements of) program ideas can be that the program has a stated aim to fulfil the CDIO Standards, or that it emphasizes a particular approach to mathematics, or that it is based on problem-based learning (PBL), has a high number of laboratory experiences or other some other main characteristics of the program.

The ***program plan*** is the formal specification of what courses are included in the curriculum, their credits and placement in the curriculum

The ***program design matrix*** connects the goals of the program with its courses so that it is clear in which course each learning outcome is addressed. The program design matrix also shows the planned learning sequences (or development routes) for learning outcomes which are developed through integrated learning experiences throughout the curriculum, typically generic competences such as communication skills.

Finally, ***course plans*** define the purpose, goals and content of each of the courses in the program, and include a statement that explains the role of the course in the program, and links it to the program goals

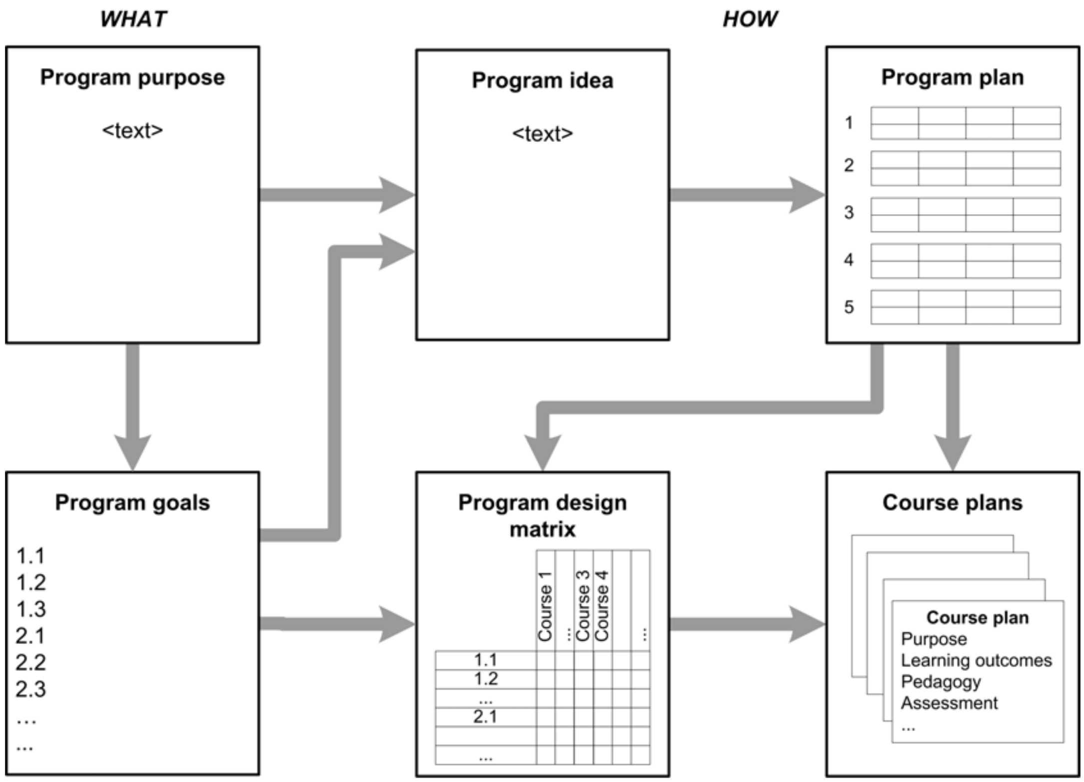

Figure 1: Integrated program description – components

Figure 1 shows the relationships between the components. A program design process that is aligned with the contents of an integrated program description typically starts with the statement of the program purpose, followed by the development and validation of the program goals. The next step is to formulate the program idea, i.e. the fundamental principles and considerations that underlie the program design. The program plan then implements the program idea, by defining the included courses, their credits and placement in the curriculum. The role of the program design matrix is then to systematically interconnect the program goals with the courses, assuring that no program goal is neglected and that there is a thought-through learning progression in the program. Finally, the course plans are developed, by refining the program goals assigned to the course, selecting pedagogical and assessment approaches and so on.

This sequence should not be enforced too strictly. It is important than the program design process allows for iterations, and makes several passes through the components. In particular, the assignment of goals for learning of generic skills needs to be done in a combined top-down and bottom-up, dialogue-rich fashion between the program chair and the involved faculty, in order to achieve commitment and to transfer ownership for such goals.

Student-led recitations – "Ticking"

- This active learning technique is appropriate in engineering subjects where the focus is on teaching problem-solving.
- For each recitation, the students are asked to prepare a set of problems. The whole class will have prepared the same problems.
- At the recitation, students tick on a list what problems they are willing and prepared to present.
- The instructor picks a student at random (or choose a student), to present the first problem on the board, after that another student is picked to do the next problem etc.
- The student must demonstrate that they have done an honest effort to prepare the problem, and be able to lead a classroom discussion to a satisfactory solution. If they fail in this, their ticks are removed (for that recitation).
- Ticking for example at least 75% of the problems is rewarded with bonus points for the exam, or it can simply be a requirement to be allowed to sit the exam.
- Note that the reward is given for the ticks themselves. As the purpose is purely formative, the quality of the presentation should not affect the grade.

Why is this an effective learning activity?

1. Ticking generates time on task

Preparing the weekly problems encourages students' to spend time on task. Notice the iceberg effect, that for every problem that we see presented by a student, up to 25 students have prepared that problem. Furthermore, the time is distributed evenly during the course. Attendance in recitations will also be very high.

2. Ticking generates appropriate learning activity

Ticking generates appropriate learning activity, as preparing the problems constitutes very good studies. Compared to just solving the problems to get them done and over with, here students will be encouraged to reflect more on the problem-solving methods as they must be prepared to explain their solution to others. Experience at KTH shows that students are positive about this active learning method, and often remark in their course evaluation that the method supports effective learning.

Note that the condition is that the problems are aligned with the intended learning outcomes of the course. The problems need to be carefully selected to illustrate the main points of the course. Do not worry that the quality of the student-led problem solving is not as good as if a teacher would present the problems. Because all students have prepared the problems, they will be able to follow the presentation, even if it is not perfect. The main point with the activity is that students will learn from preparing the problems. While the student-led presentations are what drives this, they are only the visible tip of the iceberg.

3. Ticking generates prompt feedback

The activity provides prompt feedback. Both the student who presents, and the students who listen, will have prepared the problem beforehand, and will get feedback through following the common problem-solving. The activity will often lead to very good discussions on alternative solutions, and the student leaves the session with a broader view on the problems. Depending on the nature of the subject, the teacher can hand out model solutions after the session, so all students can relate their solution to it.

4. Ticking generates feedback that the students pay attention to

Feedback has a social dimension, which will improve motivation. Coursework is useful only if students really do it. Says one student at KTH: ”*In one course we had calculations as homework twice a week. Every time the teacher picked a student at random who had to present their solution. This gave motivation [to prepare], because you did not want to stand up and say that you couldn’t do it.*” While social pressure is an important driving force for this activity, it is also important to remember that it is a strong force. It is important to create a secure and friendly atmosphere, and never ever be sarcastic to a student at the board, or allow other students to put negative pressure on a fellow student. If the situation is too stressful and threatening to the students this may counteract their learning. In fact, the student who is at the board is probably not very receptive to feedback – we all know how difficult it can be to think in real-time by the board. Think instead about how the activity will provide feedback to the whole group.

5. Ticking can help students internalize criteria for quality

Students are given the opportunity to internalize criteria for quality. They will experience presentations of different quality, and start noticing what is required of a good solution, and a good presentation. Note that this aspect may not be inherent in the method, but is an important responsibility for the teacher. The teacher will want to make sure the discussion focuses on critical aspects of the problems, and that comparisons are made between alternative solutions.

What is the teacher’s role?

- Create the appropriate problems, make sure they are aligned to the intended learning outcomes of the course.
- Use new problem sets every time the course is run.
- Ensure a positive and safe athmosphere at sessions.
- Help a student who gets stuck by inviting the class to give hints.
- Start the class in discussions on problem-solving strategies, alternative solutions, assumptions, approximations, etc.
- Hand out model solutions after the session.
- Enjoy seeing your students develop their understanding!

The analysis of ticking draws on Gibbs, G. (1999). Using assessment strategically to change the way students learn. In S. Brown & A. Glasner (Eds.) *Assessment matters in higher education.*. Buckingham, UK: SRHE and Open University Press.

Jigsaw on Teaching Methods

Method #1:
Pre-Class Readings and Homework (Look-Ahead Homework)

- Reading and homework assignments are due prior to in-class discussion of material
- Classroom interactions can focus on concepts
- Encourages self-directed learning
- Same amount of work for students, but front-loaded
- Improved feedback time
- Limitation: requires readings that students can understand on their own, *e.g.*, a good textbook

Jigsaw on Teaching Methods

Method #2:
Case Study

- Story of a real engineering experience, organization, or event

- Students face problems that are difficult for students to experience first hand, because of danger, limited access, limited equipment, etc.

- Problems that may span months or years can be addressed (and solved) in a short time

- Students have opportunities to exchange ideas with others about real engineering problems

- Limitation: finding “good” cases in specific engineering disciplines

Jigsaw on Teaching Methods

Method #3:
Simulations

- Structured situations that imitate real engineering tasks; may or may not use computer software

- Include rules, guiding principles, structured roles and relationships

- Faculty: explain roles, monitor students as they go through the simulation, help students reflect, lead the debriefing

- Debriefing looks for meaning and helps students uncover the intended ideas and principles.

Jigsaw on Teaching Methods

Method #4:
Muddiest-Part-of-the-Lecture Cards

- Statements by students about the parts of the lecture that are not clear to them

- Procedure:
  - Stop the lecture about 5 minutes before time
  - Distribute 3x5 index cards to students and ask them to write what was the "muddiest" part of the lecture for them, that is, what parts do they still not understand?
  - Collect the cards and group them by similar questions

- Answer the most common questions:
  - At the start of the next class
  - In handouts that you distribute to the class
  - On the class website

- Save the cards to improve your teaching the next time

Rating Form: Oral Presentations and Technical Briefings

Presenter: Team: Date:
Course Number and Name: Type of Presentation:
Evaluator(s):

NA = Not Applicable

	Poor	Fair	Good	Excel-lent	NA
PRESENTATION QUALITY					
Main objective of presentation is clearly stated.					
Presenter maintains good eye contact with the audience.					
Presenter uses voice effectively (volume, clarity, inflection).					
Presenter is poised and professional (appearance, posture, gestures).					
Transitions to the next presenter are smooth and effective.					
Comments on presentation skills					
TECHNICAL CONTENT					
Technical content is accurate and significant.					
Technical content shows sufficient development.					
Main points are emphasized and the relationship between ideas is clear.					
Ideas are supported with sufficient details and clear drawings.					
Graphics and demonstrations are effectively designed and used.					
Alternatives are presented with a rationale for those selected.					
Key issues are addressed.					
Questions are answered accurately and concisely.					
Comments on technical competence					

OVERALL:

Rating Form: Design Project Assessment

Student Name: ______________________ Date:_____________
Evaluator(s):__________________
Course Number and Name ________________________Team:________________________

The student demonstrated the following knowledge, skills, and attitudes:	**Not at All**	**To a Limited Extent**	**To a Moderate Extent**	**To a Great Extent**	**To a Very Great Extent**
Knowledge of Underlying Sciences (CDIO 1.1) Applies mathematics to the analysis of final design. Applies knowledge of science (physics, biology, and/or chemistry) to the analysis of final design.					
Engineering Reasoning and Problem Solving (CDIO 2.1) Applies logic in solving problems and analyzes problems from different points of view. Translates theory into practical applications using appropriate technical techniques, processes, and tools.					
Experimentation and Knowledge Discovery (CDIO 2.2) Uses computer-based and other resources effectively thus acquiring information from multiple sources. Organizes and interprets data appropriately. Designs and conducts experiments to validate theories					
System Thinking (CDIO 2.3) Understands how events interrelate and demonstrates an ability to take new information and integrate it with past knowledge from various courses, to solve technical problems.					

Creative Thinking (CDIO 2.4.3) Suggests new approaches and challenges the way things are normally done. Develops many potential solutions to problems while discouraging others from rushing to premature conclusions.					
Lifelong Learning (CDIO 2.4.6) Learns independently and continuously seeks to acquire new knowledge. Exceeds basic requirements of an assignment and brings in relevant outside experiences to provide advanced solutions to the problems at hand.					
Teamwork (CDIO 3.1) Contributes a fair share to the completion of the project. Participates, listens, and cooperates with other team members. Shares information and helps reconcile differences of opinions when they occur.					
Communication (CDIO 3.2) Articulates ideas in a clear and concise fashion and uses facts to reinforce points.. Plans and delivers oral presentations effectively. Uses technology and graphics to support ideas and decisions. Addresses questions and issues raised during the oral presentation. Written materials flow logically and are grammatically correct					
Conceiving (CDIO 4.3) Sets system goals and requirements. Defines function, concept, and architecture. Develops a realistic cost estimate to implement the design, Uses rational, objective reasoning to arrive at final design among alternatives.					
Project Management (CDIO 4.3.4) Sets goals, prioritizes tasks and meets project milestones. Seeks clarification of task requirements and takes corrective action based upon feedback from others. Creates action plans and timetables to complete assigned work.					

Designing (CDIO 4.4) Substantiates performance of final design and its elements in an objective manner and does not make unsubstantiated claims. Assesses the environmental impacts of the final design in a realistic manner. Assesses economic, social and political impact of the final design. Suggests ways to extend and improve design					

Comments:

Based on the work of McGourty, J., Sebastian, C., & Steward, W., *Gateway Coalition Freshman Design Project Faculty Review – Final Report*. See http://www.gateway.org
Adapted for *The CDIO Initiative* by D. R. Brodeur, dbrodeur@mit.edu, March 1, 2006.

Key Success Factors That Promote Cultural Change

Getting Off To the Right Start

1. **Understanding the Need for Change**
   When starting a change process, it is vital that everyone understand the need for change, and commit to the process.
   - External references to industry alumni, review committees, thought leaders, and authorities
   - Competition and benchmarking of peer programs
   - Attitude of "We can make it better" and not "It's broken and we must fix it."
   - Availability of external funding
   - Context of change, *e.g*, accreditation, the Bologna Agreement

2. **Leadership From the Top**
   Commitment of the leader is vital. Active visible support of those at levels above the leader is also important.
   - Department or program head to lead the effort
   - Strong team of key individuals in the program
   - Strong support of dean, head of school, provost, vice rector

3. **Creating a Vision**
   It is helpful if the leader communicates a vision of how the urgent need will be addressed.
   - Strike an appropriate balance in the timing of the vision
   - It may be useful to start with the CDIO vision and work from there
   - Create a vision from descriptions of the contemporary engineer

4. **Support of Early Adopters**
   In any population, on any issue, there will be those more inclined to try new approaches.
   - Identify and engage early adopters
   - Give early adopters opportunities and resources, and celebrate their successes
   - Early adopters will draw in others, by example.
   - Identify the best teachers and respected members of the community
   - Ask students and peers to identify innovative teachers
   - Announce opportunities to all and see who responds

5. **Early Successes**
   It is important to achieve some early visible successes that attract interest and stimulate efforts of all.
   - Educational change tends to be spiral or successive
   - It is better to do a quick experiment or pilot study than talk about it for years
   - Positive outcomes of pilots and experiments will attract support and interest
   - Plan to get results quickly – in one academic term or less

- Choose experiments with high visibility and wide impact

Building Momentum in the Core Activities of Change

6. **Moving Off Assumptions**
   It is necessary to get the team to move off their traditional assumptions of what and how things should be done. Change requires a willingness to think outside the box.
   - Appeal to engineers' professionalism
   - Provide evidence of what can be done and what others are doing
   - Argue positions that are independent of personal belief
   - Propose a very aggressive plan and then relax back to a more modest one
   - Involve students who can encourage slow adopters to move

7. **Including Students as Agents of Change**
   Students can provide valuable feedback on changes, especially if they understand the motivation behind the changes. They can encourage faculty in the change process.
   - Plan activities that will make students more comfortable with changes
   - Include students in planning activities to create buy-in from other students

8. **Involvement and Ownership**
   Since it will eventually be necessary to get everyone involved in the change process, it is better to start early. Academic programs are "owned" and executed by a wide range of faculty who must be satisfied, if not enthusiastic, about the change for it to take hold.
   - Work as a committee of the whole, with smaller task groups for process planning
   - Take time away to reflect and debate, preferably off site
   - Give important tasks to skeptics to win them over

9. **Adequate Resources**
   Although it is unlikely that there will be significantly new resources in the steady state for the reformed program, the change process cannot be achieved on the margin. Resources in terms of time and interim support must be made available to those participating in the reform.
   - Provide released time from teaching or other duties
   - Give extra teaching support to those willing to experiment
   - Plan summer projects

Institutionalizing Change

10. Faculty Recognition and Incentives

In any organization, you get the behavior that is rewarded. Create both the perception and reality of incentives and recognition.

- Provide recognition and awards for teaching
- Award special status for distinguished teaching and innovation
- Recognize teaching accomplishments in promotion and scholarly publications
- Include teaching in annual goals and performance review
- Recognize faculty through external awards, *e. g*. the National Academy of Engineering (U.S.)

11. Faculty Learning Culture

Ironically, many universities do not have a culture in which learning by the faculty is valued. Create the expectation and set the standard that lifelong learning is vital for the faculty, not only in their disciplines, but in other aspects of their professions, including CDIO and teaching skills.

- Give faculty leave for professional development
- Circulate and discuss relevant publications
- Ask faculty to develop annual professional development plans
- Create learning opportunities for faculty in the program

12. Student Expectations and Academic Requirements

Students are the immediate customers and beneficiaries of the education. A program has one chance to make a good impression.

- Give clear explanations of the program to students right at the start
- Establish the expectations that students are required to be active participants in their own learning
- Share expected learning outcomes with students

CDIO Initiative
Frequently **A**sked **Q**uestions (and Answers)

May 2005

Curriculum

- *How do you find space in an already crowded curriculum?*
  CDIO learning outcomes are not added to a curriculum, but integrated with disciplinary concepts and skills. For example, problem solving, modeling, and experimentation become the vehicle for learning about thermodynamics; or, principles of mechanical engineering are applied in the conception and design of products and processes. This dual use of time makes it possible to address CDIO learning outcomes without sacrificing depth in the disciplines.

- *What do we take out of the curriculum to make room for CDIO?*
  Too often, engineering education has been a case of "data streaming", covering a wide range of topics without sufficient time to promote deep conceptual learning. By concentrating on key concepts and skills and demonstrating connections with other concepts and skills, instructors create opportunities for deeper learning. The focus changes from "coverage" to student-centered approaches to learning.

- *Are we "dumbing down" the curriculum?*
  No. Teaching and learning of disciplinary content is as rigorous as ever. The change in curriculum is in its emphasis on understanding critical concepts that underlie each discipline, making connections among ideas, and applying knowledge to the real world of engineering practice.

Establishing Buy-In

4. *How do we get buy-in from program leaders, faculty, and students?*
   According to the literature on the change process, ten factors promote cultural change:
   - Understanding of the need for, and a commitment to, change
   - Leadership from the top
   - Identification and support of early adopters
   - Early visible successes to attract interest and motivate efforts
   - A willingness to think outside the box
   - Involvement of a wide cross-section of constituents
   - Adequate resources
   - Incentives and rewards aligned with intended changes
   - The expectation of lifelong learning for faculty, including CDIO and teaching skills
   - Involvement of students and other stakeholders

5. *Why should we change if everything is fine now?*
   Educational reform should be viewed as a process of continuous improvement to already effective programs, not necessarily as a "fix" to something that is broken.

Resources

6. *What level of resources is required to adopt or adapt CDIO?*
   Descriptions of early successes and start-up guidance, found at the CDIO web site, suggest levels of resources required to adopt CDIO in programs that differ in size, in disciplinary content, and in institutional environment.

7. *How much time does it take?*
   In our experience, it takes about two years to plan and implement a CDIO program, and about four additional years before results are seen in graduating students.

8. *How do we scale design-implement experiences for larger groups or programs with scarce resources?*
   All design-build projects do not have to include high levels of complexity, technology, and resources. The Implementation Kit (I-Kit) found at the CDIO web site offer suggestions for scaling design experiences to large groups of students or programs with scarce resources.

9. *Where do we get resources and space to execute design-build experiences for all students?*
   Re-task existing labs and workspaces to accommodate students. Extend hours in which workspaces are accessible to student groups. Use cooperative learning strategies in which students have designated roles, responsible for contributing components of complex systems, products, or processes. Create simulations or computer models of design-build experiences.

10. *Does CDIO work in programs that have more than 300 students?*
    Yes. There are several examples of existing CDIO programs that have more than 180 students per class. The Engineering Department at Cambridge University offers design-implement experiences for 300+ students.

Faculty Development

11. *How do we influence tenure and promotion policies to support faculty adoption of CDIO approaches?*
    This is an issue that has to be addressed. The program, school, and university must send a clear message that research and development in curriculum, teaching, and learning are important components of faculty responsibility and workload. Tenure and promotion policies and practices must be aligned with the commitment to student-centered learning (CDIO) approaches.

12. *Where do you find teaching, learning, and assessment expertise?*
    The Implementation Kit (I-Kit) and the Instructor Resource Materials (IRMs) at the CDIO web site are good places to start. Teaching and Learning Centers at your university are often willing to lend their expertise, or collaborate in the implementation of CDIO. Professional organizations, *e.g.*, ASEE, SEFI, publish conference proceedings on teaching, learning, and assessing engineering education.

Evaluation

13. How do we know that CDIO is an improvement?

To be able to show the difference that CDIO makes, it is important to implement a program evaluation process that gathers data aligned with key programmatic questions. Success, or improvement, measures may vary from program to program. Measures of success may include: increased enrollment and retention in program; increased satisfaction of students, faculty, and key stakeholders; achievement of a broader range of program objectives, increase in student awards and recognition by external professional groups; or, increased placement rates in relevant industries.

14. Would we be able to change back later if CDIO is not effective for us?

There are no irreversible changes in the implementation of a CDIO program. However, it is our experience that students respond well to CDIO learner-centered approaches, and that once they are removed, they are less satisfied with their education than before the experience.

15. Where is the market for graduates of CDIO programs?

Because CDIO programs and approaches were developed in response to industry requirements, graduates of CDIO programs are likely to be more attractive to these industrial partners. Moreover, CDIO programs encourage closer ties with industrial partners throughout students' experiences, through design-build experiences, internships, and funded research. These opportunities create good relationships in the job market even before students graduate.

Selected References That Support the CDIO Workshop

Engineering Education -- General

Crawley, E.F., Malmqvist, J., Östlund, S., & Brodeur, D. R. (2007). *Rethinking engineering education: The CDIO approach.* New York: Springer.

Heywood, J. (2005). *Engineering education: Research and development in curriculum and instruction.* New York: Wiley.

Journal of Engineering Education, 94 (1), January 2005. Special issue: The Art and Science of Engineering Education Research.

The CDIO Syllabus

Bankel, J., Berggren, K. F., Blom, K., Crawley, E. F., Wiklund, I., & Östlund, S. (2003). The CDIO Syllabus: A comparative study of expected student proficiency. *European Journal of Engineering Education, 28* (3), 297-315. Available at http://www.cdio.org

Crawley, E. F. (2001). *The CDIO Syllabus: A statement of goals for undergraduate engineering education*. Available at http://www.cdio.org

Integrated Curriculum

Bankel, J., Berggren, K. F., Crawley, E. F., Engström, M., El Gaidi, K., Wiklund, I., S. Östlund, S., & Soderholm, D. H. (2005). Benchmarking engineering curricula with the CDIO Syllabus. *International Journal of Engineering Education, 21* (1). Available at http://www.cdio.org

Barrie, S. C. (2004). A research-based approach to generic graduate attributes. *Higher Education Research and Development, 23* (3), August.

Berglund, F., & Malmqvist, J. (2007). CDIO-based master programme in product development. *Proceedings of the 3rd International CDIO Conference*, MIT, Cambridge, Massachusetts, June 11-14, 2007. Available at http://www.cdio.org

Malmqvist, J., Östlund, S., & Edström, K. (2006). Integrated program descriptions: A tool for communicating goals and design of CDIO programs. *Proceedings of the 2nd International CDIO Conference*, Linköping University, Linköping, Sweden, June 13-14, 2006. Available from the authors.

Design-Implement Experiences

Edström, K., Hallström, S., El Gaidi, K., & Kuttenkeuler, J. (2005). Integrated assessment of disciplinary, personal, and interpersonal skills: Student perceptions of a novel learning experience. *Proceedings of the 13th Improving Student Learning Conference*, Oxford, UK, OCSLD. Available from the authors.

Hallström, S., Kuttenkeuler, J., & Edström, K. (2007). The route towards a sustainable design-implement course. *Proceedings of the 3rd International CDIO Conference,* MIT, Cambridge, Massachusetts, June 11-14, 2007. Available at http://www.cdio.org

Malmqvist, J., Young, P.W., Hallström, S., Kuttenkeuler, J., & Svensson, T. (2004). Lessons learned from design-build-test-based project courses. *International Design Conference – Design 2004*, Dubrovnik, Croatia, May 18-21, 2004. Available at http://www.cdio.org

Active Learning

Barkley, E. F., Cross, K. P., & Major, C. H. (2005). *Collaborative learning techniques: A handbook for college faculty*. San Francisco, CA: Jossey-Bass.

Biggs, J. B. (2003). *Teaching for quality learning at university: What the student does.* 2nd Ed. Buckingham, England: The Society for Research into Higher Education and Open University Press.

Bransford, J. D., Brown, A. L., & Cocking, R. R. (Eds.). (2000). *How people learn: Brain, mind, experience, and school.* Washington, DC: National Academy Press.

Gibbs, G. (1999). Using assessment strategically to change the way students learn. In Brown, S., & Glasner, A. (Eds.). Assessment matters in higher education. Buckingham, UK: Society for Research into Higher Education and Open University Press.

Goodhew, P.J., & Bullough, T. J. (2005). *Active learning in materials science*. Available at http://www.cdio.org

Hall, S. R., Waitz, I., Brodeur, D. R., Soderholm, D. H., & Nasr, R. (2002). *Adoption of active learning in a lecture-based engineering class*. Proceedings of the 32nd ASEE/IEEE Frontiers in Education Conference, Boston, November 2002. Available at http://fie.engrng.pitt.edu

Experiential Learning

Andersson, S., Edström, K., Eles, P., Knutson Wedel, M., Engström, M., & Soderholm, D. H. (2003). *Recommendations to address the barriers in CDIO project-based courses. A CDIO Report*. Available at http://www.cdio.org

Brodeur, D. R., Young, P. W., & Blair, K. B. (2002). *Problem-based learning in aerospace engineering education*. Proceedings of the 2002 American Society of Engineering Education Annual Conference and Exposition. Available at http://www.asee.org/conferences/v2search.cfm

Knowlton, D. S., & Sharp, D. C. (Eds.). (2003). *Problem-based learning in the information age*. New Directions for Teaching and Learning, No. 95. San Francisco, CA: Jossey-Bass.

Kolb, D. A. (1984). *Experiential learning*. Upper Saddle River, NJ: Prentice-Hall.

Savin-Baden, M., & Major, C. H. (2004). *Foundations of problem-based learning.*. Berkshire, England: Society for Research into Higher Education and Open University Press.

Learning Assessment

Angelo, T. A., & Cross, P. K. (1993). *Classroom assessment techniques: A handbook for college teachers,* 2d ed. San Francisco, CA: Jossey-Bass.

Field-Tested Learning Assessment Guide. Available at http://www.flaguide.org

Huba, M. E., & Freed, J. E. (2000). *Learner-centered assessment on college campuses*. Boston, MA: Allyn and Bacon.

Wiggins, G., & McTighe, J. (1998). *Understanding by design*. Alexandria, VA: Association for Supervision and Curriculum Development.

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SUMMARY

"How much progress did you make toward the workshop objectives?

	Little or no progress	Some progress	Very good progress
Explain the CDIO approach to engineering education			
Determine ways in which the CDIO approach may be adapted to your own programs			
Share your ideas and experiences of engineering education reform			
Other (please specify)			

Please write additional comments on the back of this page.