Program Evaluation Aligned With the CDIO Standards

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Abstract

The CDIO Initiative is a collaboration of engineering programs at universities in more than eight countries in North America, Europe, Africa, Asia, and Australia. Collaborators have developed a set of twelve standards that characterize CDIO programs and provide the basis for program evaluation. This standards-based program evaluation extends the evaluative criteria of ABET's *EC2000* and other outcomes-based approaches. Evidence of overall program value is collected from multiple sources, using both quantitative and qualitative methods. Evidence and results form the basis of decisions about the program and its plans for continuous improvement.

This paper describes a standards-based approach to program evaluation and provides a rationale for the CDIO standards in reforming engineering education. The main objectives of the paper are to

- identify key questions that guide program evaluation and set them in the framework of the CDIO standards
- compare the CDIO standards with criteria set forth by ABET in *EC2000*
- give examples of standards-based program evaluation of engineering programs
- emphasize the connection between program evaluation and program improvement

Background

In October 2000, the Massachusetts Institute of Technology, Chalmers University of Technology, the Royal Institute of Technology, and Linkoping University launched a project to reform undergraduate engineering education.[1] Sponsored in part by the Wallenberg Foundation[2], *The CDIO Initiative* has expanded to include programs in more than eight countries on five continents. Descriptions of the project and its global implementation can be found at http://www.cdio.org.[3]

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. This context is a generalized description of a complete system life cycle, called in this project, *Conceive-Design-Implement-Operate*. The *Conceive* stage includes defining the need and technology, considering the enterprise strategy and regulations, developing the concept, architecture, and business case. The second stage, *Design*, focuses on creating the design, *i.e.*, the plans, drawings, and algorithms that describe what will be implemented. *Implement* refers to the transformation of the design into the product, including manufacturing, coding, test and validation. The final stage, *Operate*, uses the implemented product to deliver the intended value, including maintaining, evolving and retiring the system.

The CDIO Initiative focuses on the reform of curriculum, teaching and learning methods, learning assessment, design-build experiences, and the creation and re-tasking of laboratories and workspaces. One of its major accomplishments is the development of standards that characterize the essential features of a CDIO program. These standards form the framework for program evaluation and plans for continuous improvement.

Standards-Based Program Evaluation

In the educational evaluation literature, program evaluation is sometimes referred to as program assessment. *The CDIO Initiative* uses the term 'evaluation' to mean a judgment of the overall value of a program based on evidence of a program's progress toward attaining its goals. We apply the term 'assessment' to the measure of the extent to which each student achieves specified learning outcomes. Instructors usually conduct this assessment within their respective courses. We recognize that the terms are sometimes used interchangeably, but for the sake of clarity, we use 'evaluation' for programs, and 'assessment' for student learning at the course level. In her work on evaluation, Weiss describes evaluation as "the systematic assessment of the operation and/or the outcomes of a program or policy compared to a set of explicit standards, as a means of contributing to the improvement of the program or policy."[4] The emphasis on system indicates that evaluation is conducted with formality and rigor, according to accepted social science research methods.

Some evaluations concentrate on the outcomes and effects of the program for its intended stakeholders, while others focus on studying process, *i.e*., the way a program is conducted. Many program accreditation groups, *e. g.*, ABET and the New England Association of Secondary Schools and Colleges, have moved in the direction of outcomes-based evaluation. Evaluation assesses the merit of a program by comparing the evidence collected to some set of expectations. Evaluation is designed to help make programs work better and to allocate resources to improve programs.

Standards-based program evaluation has features in common with other types of evaluation, *e.g.,* outcomes-based evaluation, process evaluation, impact evaluation. Outcomes-based evaluation focuses on the end results of the program for the people it was intended to serve. Some outcomes are intentional, while others are unanticipated. Process evaluation is the systematic assessment of what is happening inside the program. Examination of the process helps to explain the program outcomes, and points to features of the program that have greater or less success.[4] An impact study looks at what happens to participants as a result of the program. Sometimes impact is construed as long-term outcomes. Occasionally, impact means effects of the program on the larger community.

A CDIO standards-based program evaluation focuses on outcomes, particularly student learning outcomes and student satisfaction, and process, particularly teaching, learning, and assessment in a design-build environment. Programs are compared to an explicit set of expectations, namely the 12 CDIO standards. While the standards do not specifically address long-term impact, the evaluation of CDIO programs often includes questions related to students' future plans, alumni contributions to their engineering fields, and influences of a program on local, national, and international industries.

The CDIO Standards

A CDIO standard describes an essential characteristic of an engineering program that has adopted the CDIO model of engineering education reform. The twelve standards were developed in response to requests from industrial partners, program leaders, and alumni for attributes of graduates of CDIO programs. That is, they 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
- create benchmarks and goals that can be applied world wide
- provide a framework for self-evaluation and continuous improvement

Taken individually, the CDIO Standards add little new knowledge of effective engineering education research and practice. However, taken as a whole, the twelve CDIO standards provide a comprehensive approach to the reform and improvement of engineering programs. Other ASEE papers have addressed specific standards, citing related research, and giving examples of best practice. (See the attached Bibliography for examples.)

The twelve CDIO standards address program philosophy (Standard 1), curriculum development (Standards 2, 3 and 4), design-build 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). For each standard, the description explains the meaning of the standard; and the rationale highlights reasons for setting the standard. Later in the paper, we give examples of documentation and events that provide evidence of progress toward the attainment of each standard.

Standard 1 -- 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

Description: A CDIO program is based on the principle that product and system lifecycle development and deployment are the appropriate context for engineering education. *Conceiving--Designing--Implementing--Operating* is a model of the entire product lifecycle. CDIO 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.

Rationale: Beginning engineers should be able to *Conceive--Design--Implement--Operate* complex value-added engineering products 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.

Standard 2 -- 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

Description: The knowledge, skills, and attitudes intended as a result of engineering education, *i.e.,* the *learning outcomes*, are codified in the *CDIO Syllabus*.[8] These learning outcomes, also called learning objectives, 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, interpersonal, and product 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 and system building skills (Section 4) focus on conceiving, designing, implementing, and operating systems in enterprise, business, and societal contexts.

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.

Standard 3 -- Integrated Curriculum

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

Description: A CDIO curriculum includes learning experiences that lead to the acquisition of personal, interpersonal, and product and system building skills (Standard 2), integrated with the learning of disciplinary content. Disciplinary subjects 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 CDIO skills and multidisciplinary connections are to be made, for example, by mapping CDIO learning outcomes to courses and co-curricular activities that make up the curriculum.

Rationale: The teaching of personal, interpersonal and product 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 both disciplinary and personal, interpersonal, and product and system building 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 CDIO learning outcomes in their respective teaching areas.

Standard 4 -- 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

Description: The introductory course 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 knowledge, skills, and attitudes that are essential at the start of a program to prepare students for more advanced product and system building experiences. For example, students can participate in small team exercises to prepare them for larger product-based 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*.

Standard 5 -- Design-Build Experiences

A curriculum that includes two or more design-build experiences, including one at a basic level and one at an advanced level

Description: The term *design-build experience* denotes a range of engineering activities central to the process of developing new products and systems. Students develop product and system building skills, as well as the ability to apply engineering science, in design-build experiences integrated into the curriculum. Design-build 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-build experiences appear in later courses designed to help students integrate knowledge and skills acquired in preceding courses and learning activities.

Rationale: Design-build experiences are structured and sequenced to promote early success in engineering practice. Iteration of design-build experiences and increasing levels of design complexity reinforce students' understanding of the product and system development process. Design-build 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.

Standard 6 -- CDIO Workspaces

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

Description: Workspaces and laboratories support the learning of product 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 the process of designing, building, and testing products 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 and system building competencies. These competencies are developed in workspaces that are student-centered, user-friendly, accessible, and interactive.

Standard 7 -- Integrated Learning Experiences

Integrated learning experiences that lead to the acquisition of disciplinary knowledge, as well as personal, interpersonal, and product and system building skills

Description: Integrated learning experiences are pedagogical approaches that foster the learning of disciplinary knowledge simultaneously with personal, interpersonal, and product 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 both disciplinary skills and personal, interpersonal and product 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.

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-build projects, simulations, and case studies.

Rationale: Students remember less than a fourth of what they hear and only about half of what they see and hear. 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.

Standard 9 -- Enhancement of Faculty CDIO Skills

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

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

Standard 10 -- Enhancement of Faculty Teaching Skills

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). 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 skills.

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 skills. Many universities have faculty development programs and services that might be eager to collaborate with CDIO program faculty. 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.

Standard 11 -- CDIO Skills Assessment

Assessment of student learning in personal, interpersonal, and product 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, interpersonal, and product 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, interpersonal, and product and system building skills, set them as learning outcomes, and design them into curriculum and learning experiences, then we must have effective assessment processes for measuring these skills. 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-build skills may be better measured with recorded observations.

Standard 12 -- CDIO 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. Moreover, many external evaluators and accreditation bodies require regular and consistent program evaluation.

Program Evaluation Aligned with the CDIO Standards

As illustrated in Figure 1, evaluation of a CDIO program focuses on the objectives and outcomes of the program and the processes that contribute to students' achieving those. outcomes: program goals, curriculum, teaching and learning methods, the learning environment, learning assessment, and faculty development. Note that program evaluation is irself one of the standards.

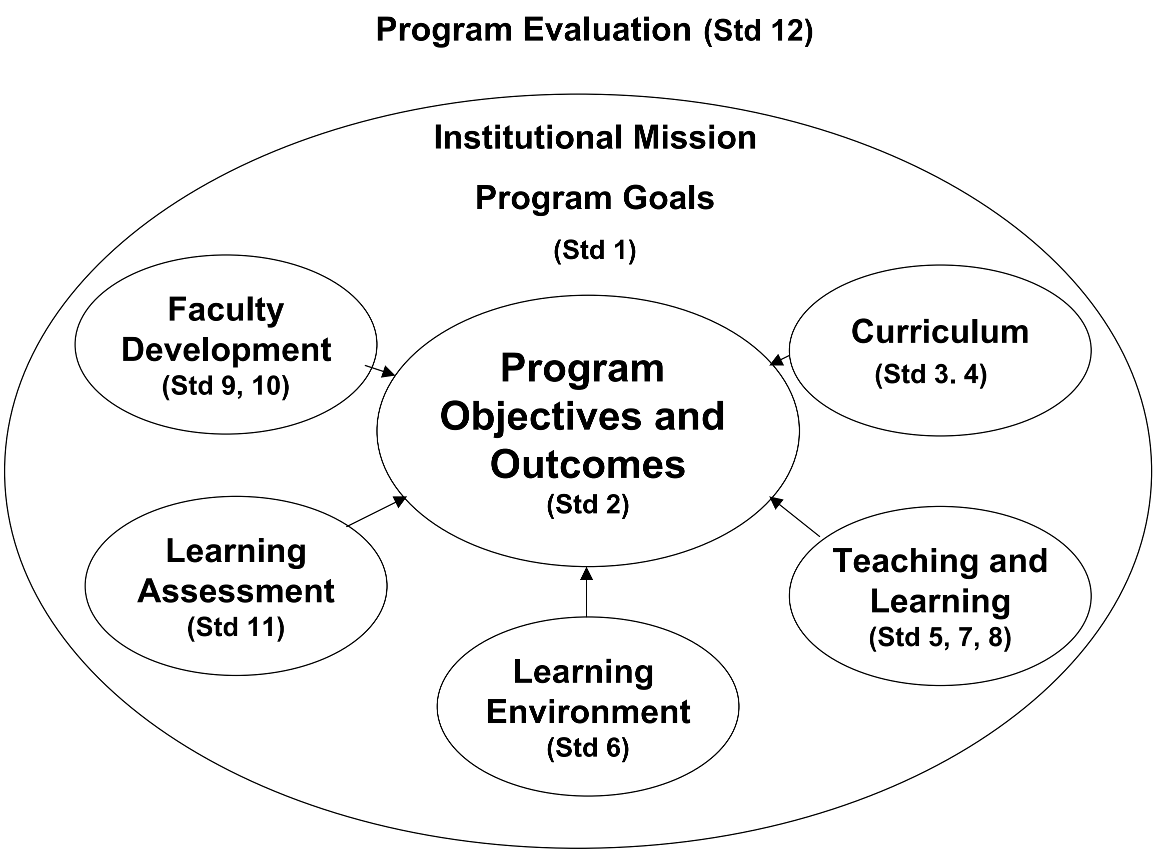

Figure 1. Program Evaluation Aligned With the CDIO Standards

Table 1. Key Questions Aligned with the CDIO Standards

KEY QUESTIONS	STANDARD
What are the objectives and outcomes of a CDIO program? How are they aligned with institutional mission and program goals? What is the context for these objectives and outcomes?	1 and 2
How does a CDIO curriculum contribute to the attainment of program outcomes? How are CDIO outcomes integrated into the curriculum?	3
How do first-year courses introduce the CDIO context and motivate students to choose engineering programs?	4
How do active and experiential methods contribute to the attainment of program outcomes in a CDIO context? How are these learning experiences integrated into the engineering program?	5, 7, and 8
How does the learning environment contribute to the attainment of CDIO program objectives and outcomes?	6
What have students achieved with respect to program outcomes? How are CDIO learning outcomes measured and documented?	11
How are faculty development and motivation encouraged? How do faculty roles change in a CDIO context? How satisfied are faculty with the teaching and learning experiences?	9 and 10
Is there a systematic process in place to evaluate CDIO program outcomes and processes? Are the evaluation results used in continuous process improvement?	12

CDIO Standards and National Standards

The CDIO standards supplement national accreditation standards that establish basic levels of performance required for certification or accreditation. A program that meets the CDIO standards necessarily will meet the criteria of most accrediting bodies. As an example, Table 2 compares the CDIO standards with ABET's evaluation criteria set forth in *EC2000*.[6] Similar comparisons are being developed for engineering programs in Sweden, Denmark, the United Kingdom, Canada, and South Africa.

Table 2. CDIO Standards Compared With ABET's *EC2000*

CDIO STANDARD	*EC2000* (ABET)
1. Adoption of a mission that includes the principle that product and system lifecycle development and deployment – Conceiving, Designing, Implementing and Operating - are the context of engineering education	No explicit statement, but implicitly engineering science is the context.
2. Specific, detailed learning outcomes that describe professional knowledge, skills, and values that support product and system building competencies, consistent with program mission and validated by program stakeholders	Criterion 2a.Detailed published educational objectives that are consistent with the mission of the institution and these criteria Criterion 2b. A process based on the needs of the program's various constituencies in which objectives are determined and periodically evaluated

3. A curriculum designed with mutually supporting disciplinary subjects, with an explicit plan to develop professional knowledge, skills, and values that support product and system building competencies	Criterion 2c. A curriculum and process that ensures the achievement of the program objectives Criterion 4. A general education that complements technical content of curriculum and is consistent with program and institution objectives
4. An introductory course that provides the framework for engineering practice in product and system building, and introduces essential professional knowledge, skills, and values that support product and system building competencies	Not addressed
5. A curriculum that includes two or more design-build experiences, including one at a basic level and one at an advanced level	Criterion 4. Curriculum to culminate in a major design experience, based on knowledge and skills acquired in earlier coursework.
6. Workspaces and laboratories that support and encourage hands-on learning of product and system building skills, disciplinary knowledge, and teamwork abilities	Criterion 6. Classrooms, labs, and equipment must be adequate to accomplish program objectives, foster faculty-student interaction, encourage student professional development
7. Learning experiences that support the acquisition of technical knowledge as well as the professional knowledge, skills, and values that support product and system building competencies	Not addressed
8. Teaching and learning methods based on active experiential learning models	Not addressed
9. Actions that enhance faculty competence in essential professional knowledge, skills, and values that support product and system building competencies	Criterion 5. General requirements for faculty competence, but no explicit requirement for system–building skills
10. Actions that enhance faculty competence in active experiential teaching and learning, and assessment	Not addressed
11. Assessment of student learning in professional knowledge, skills, and values that support product and system building competencies	Criteria 3a - 3k. An assessment process to demonstrate that graduates have developed a set of specific attributes and abilities, listed in a through k.
12. An evaluation system that includes a continuous program improvement loop intended to provide feedback to students, faculty, program planners, and funding agencies	Criterion 2d. A system of ongoing evaluation that demonstrates achievement of program objectives, and uses the results to improve the effectiveness of the program

The CDIO program evaluation approach expands ABET *EC2000* particularly in the areas of teaching and learning, and the consequent need for faculty development. A CDIO program recognizes that a shift in focus, context, and outcomes requires support for instructional staff. If faculty are expected to integrate all CDIO learning outcomes into their courses, they need to enhance their own experiences in them. And if new program outcomes require new methods of teaching, learning, and assessment, faculty need support to make these changes, as well. A CDIO program evaluation examines the nature and level of support that is provided to the entire instructional staff.

Evidence and Methods Aligned with the CDIO Standards

A planning matrix, similar to the one shown in Table 3, helps to organize the data collection activities. In evaluating CDIO programs, we use multiple data collection methods to gather data from students, faculty, existing documents, and other institutional sources.

Table 3. Evidence and Data Collection Aligned with the CDIO Standards

CDIO STANDARD	SAMPLE EVIDENCE	DATA COLLECTION METHOD
1. CDIO as Context	Documented mission statement Faculty and student who can articulate mission	Review of existing documents Focus group interviews
2. CDIO Syllabus Outcomes	Lists of program learning outcomes Validation for content and proficiency levels with key stakeholders	Document review Institutional self-studies Surveys of key stakeholder groups
3. Integrated Curriculum	Documented plan of CDIO skills integration Inclusion of CDIO skills in courses	Curriculum mapping Instructor reflective memos Interviews of instructors
4. Introduction to Engineering	Student acquisition of essential CDIO skills High student interest in engineering Selection of engineering major	Course-embedded assessment Course evaluation Focus group interviews Exit surveys
5. Design-Build Experiences	Two or more design-build courses in the curriculum Co-curricular opportunities	Curriculum review Course evaluation Exit surveys
6. CDIO Workspaces	Adequate spaces and engineering tools High levels of student satisfaction	Space usage studies Exit surveys Instructor reflective memos
7.Integrated Learning Experiences	Evidence of CDIO skills and disciplinary skills in learning experiences Involvement of key stakeholders	Instructor reflective memos Course-embedded learning assessment Stakeholder surveys
8. Active Learning	Successful implementation of active learning methods High levels of student achievement and satisfaction High levels of faculty interest in active learning methods	Course-embedded learning assessment Instructor reflective memos Course evaluations Focus group interviews Exit surveys
9. Enhancement of Faculty CDIO Skills	Commitment of resources to faculty development Majority of faculty with competence in CDIO	Annual faculty review Resource allocation studies Instructor reflective memos
10.Enhancement of Faculty Teaching Skills	Commitment of resources to faculty development Majority of faculty with competence in teaching and assessment methods	Annual faculty review Resource allocation studies Instructor reflective memos
11.CDIO Skills Assessment	Assessment methods matched to learning outcomes Successful implementation of assessment methods	Course syllabi Course-embedded learning assessment Instructor reflective memos
12. Program Evaluation	Documented continuous improvement process Evidence of data-driven changes	Document review Interviews of decision-makers

Most of the methods listed in Table 3 are traditional data collection methods familiar to those responsible for educational program evaluation. Two of them, however, may require clarification: course-embedded assessment and instructor reflective memos. We use course-embedded assessment to gather data for evaluation questions related to Standards 4, 7, 8, and 11. In fact, Standard 11 focuses on those learning assessment methods that instructors use to determine if students have met the intended learning objectives. These methods include oral and written examinations, performance ratings of oral presentations and laboratory work, colleague and self-assessment, professional journals and design portfolios.

As shown in Table 3, some CDIO programs use instructor reflective memos to collect data for evaluation questions related to Standards 3, 6, 7, 8, 9 10, and 11. At the end of the term, faculty members are asked to write 4-to-6-page memos, summarizing their experiences with teaching, learning, and assessment in their respective courses. They are asked to address the intended learning objectives and evidence that they have been met; ways in which CDIO skills have been integrated into their courses; evidence that their teaching and assessment methods have been effective; their plans to improve the course in subsequent offerings; and, names of faculty with whom they will share the memo. Each faculty member meets with the program head, or the person responsible for instructional quality, to discuss the memo and other issues related to curriculum and instruction. In some cases, the memos are then forwarded to an evaluation specialist who summarizes program-wide themes and trends.

Self-Evaluation and the CDIO Standards

Similar to most judgment models of evaluation, accreditation for example, determination of a program's progress toward the CDIO standards is accomplished through self-evaluation. Each program describes its evidence related to each of the twelve standards. A 5-level rating scale is used to indicate progress toward the planning, implementation, and adoption of each CDIO standard. As seen in the rating levels, planning, implementation and adoption of the CDIO standards is not a linear process, but involves iteration and spiraling. The rubric has been designed deliberately to encourage planning and allow various styles of implementation and adoption. All programs in the *CDIO Initiative* use this rubric for self-evaluation against the twelve standards.

Rating Scale:
0. No initial program-level plan or pilot implementation
1. Initial program-level plan and pilot implementation at the course or program level
2. Well-developed program-level plan and prototype implementation at course and program levels
3. Complete and adopted program-level plan and implementation of the plan at course and program levels underway
4. Complete and adopted program-level plan and comprehensive implementation at course and program levels, with continuous improvement processes in place

In addition to the numerical ratings, each CDIO program describes the evidence that is the basis for the rating of each standard. If the program is not completely satisfied with its rating, it plans specific actions to accelerate progress. Table 4 gives an example of the evidence of progress toward the 12 standards and the corresponding self-evaluative rating for MIT's program in Aeronautics and Astronautics in October 2004. Recommended actions for continuous improvement are discussed in the next section. Each CDIO program has completed similar tables.

Table 4. Program Self-Evaluation Based on the CDIO Standards
MIT Aeronautics and Astronautics Program -- October 2004

EVIDENCE OF PROGRESS	RATING
1. CDIO as Context The mission of the AA Department is to prepare engineers for success and leadership in the conception, design, implementation, and operation of aerospace and related engineering systems (Strategic Plan, 1998) The mission was adopted in 1998 and provides the framework for subsequent curriculum reform. Descriptions appear in MIT publications and web sites.	4
2. CDIO Syllabus Outcomes The *CDIO Syllabus* focuses on personal, interpersonal, and product and system building skills, and includes disciplinary fundamentals appropriate for aerospace and related engineering systems. The Syllabus was validated with program stakeholders in 1999 and 2000.	4
3. Integrated Curriculum A curriculum that weaves personal, interpersonal, and product and system skills into disciplinary courses was designed in 2002 for pilot implementation in Fall 2002 and full implementation in Fall 2003. Every course has a plan outlining the CDIO skills that should be integrated, as well as the degree of implementation.	3
4. Introduction to Engineering *Unified Engineering I and II* is a yearlong course of 48 units (approx. 12 sem. cr.) that includes fluid mechanics, structures and materials, software and computation, signals and systems, thermodynamics, and propulsion. A series of systems problems introduces students to the practice of engineering. The deliberate teaching of CDIO skills began in Fall 2002. End-of-course student ratings show high satisfaction with this course.	4
5. Design-Build Experiences In *Unified Engineering I-II* (described above), second-year students design, build and fly radio-controlled electronic propulsion aircraft. In capstone courses, third-and fourth-year students design, experiment, test, and build complex systems that integrate engineering fundamentals in a multidisciplinary approach. A new capstone course in aeronautics was offered for the first time in Fall 2003.	4

6. CDIO Workspaces The Learning Laboratory for Complex Systems that opened in 2000 and the renovations in Building 33 provide support for hands-on learning of CDIO skills, with a special emphasis on product and system building. Spaces are designated for each of the four phases of product and system building: C-D-I-O. In exit interviews, students identified the lab spaces as a major contributing factor to their sense of community rapport and their satisfaction with the AA program	4
7. Integrated Learning Experiences Experimental and design projects in the research and capstone courses are typical of those encountered in the aerospace industry. Design problems are chosen to encourage original solutions and applications. Consequently, finding new projects each year is a challenge.	3
8. Active Learning In lecture-based courses, instructors are using reading quizzes, muddiest-point-in-the-lecture cards, concept tests, personal response systems, turn-to-your-partner discussions, and demonstrations. In laboratory, research, and design courses, instructors use demonstrations, inquiry, projects, problem solving, and experimentation. Course evaluations provide evidence of the effectiveness of these active learning teaching methods. The number of instructors using active learning has increased in the last three years.	3
9. Enhancement of Faculty CDIO Skills The A-A Department has taken a number of actions to enhance faculty competence in CDIO skills: hiring new faculty with CDIO expertise, sponsoring faculty's working in industry, sabbaticals in engineering practice. With the help of the AA Department, the CDIO Initiative is developing Instructor Resource Modules to support faculty in the teaching of CDIO skills.	4
10. Enhancement of Faculty Teaching Skills Faculty members are expected to show personal development in teaching, learning, and assessment methods during their annual performance review. Forty percent of annual raises are earmarked for teaching improvement. Moreover, faculty are expected to write reflective memos that map specific plans for improving teaching, learning, and assessment in their courses. Presentations, demonstrations, and short courses are available, both in the department and through MIT's Teaching Learning Lab. The number of faculty presenting at conferences on education topics has increased in the past two years.	3
11. CDIO Skills Assessment Within courses, faculty use traditional and newly designed tools to assess student achievement of course learning outcomes, including oral exams, concept questions, peer assessment of projects and presentations, and reflective portfolios. There is a department assessment and evaluation plan with a few pilot implementation projects.	3
12. CDIO Program Evaluation The department has a comprehensive plan for program evaluation and well as several tools in place. The Undergraduate Committee examines data from subject evaluations, baseline interviews, exit interviews, and surveys for continuous process improvement. Evidence of achievement of CDIO skills is inferred from senior interviews and surveys. The department also participates in program evaluation by ABET, EBI, COFHE and other external evaluation agencies.	3

Continuous Program Improvement

Self-evaluation provides opportunities to not only rate current status, but also plan specific actions for continuous program improvement. *The CDIO Initiative* collaboration also provides support from colleagues through joint projects and shared best practice related to each standard. As an example, MIT planned these actions following its self-evaluation in October 2004:

- Monitor the integration of CDIO skills into each course and revise course CDIO plans where necessary (Std 3)
- Monitor and support the newer capstone course in aeronautics and investigate ways to include more "build" experiences into the program (Std 5)
- Investigate new sources of challenging design problems (Std 7)
- Incorporate the experiences and best practices of successful instructors (Std 8)
- Make connections from professional development activities to more effective student learning and satisfaction (Std 10)
- Expand the set of tools for assessing CDIO skills and extend the use of these tools to at least 50% of the courses (Std 11)
- Close the loop on data collection and process improvement (Std 12)

Summary

The twelve standards developed by *The CDIO Initiative* serve as a useful framework for program self-evaluation. Chalmers University of Technology, the Royal Institute of Technology, Linkoping University, and the Massachusetts Institute of Technology have been using this model of self-evaluation since October 2000. New collaborators -- more than a dozen engineering programs -- conduct similar self-evaluations as they begin their reform process and as they project their desired status in two to five years. In Sweden, academic groups responsible for the evaluation of higher education programs have adopted the CDIO standards as the basis of their evaluation processes. The standards are also consistent with evaluative criteria in the United States, Canada, the United Kingdom, and South Africa. With its emphasis on continuous program improvement, the CDIO standards-based approach enhances accreditation reviews. At least annually, a CDIO program identifies specific tasks related to each standard to improve the program overall.

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