

The application of CDIO Standards in the evaluation of Swedish engineering degree programmes

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ABSTRACT: In this article, the authors report on a large-scale application of the *Conceive – Design – Implement – Operate* (CDIO) Standards, involving approximately 100 educational programmes. The context is the Swedish national evaluation of its *civilingenjör* engineering degree programmes undertaken by the Swedish National Agency for Higher Education (Högskoleverket, HSV). The authors first briefly describe the CDIO Standards focusing on their role as a support for continuous programme development. The authors then outline the HSV evaluation process and account for HSV's motives for including the CDIO Standards evaluation in the self-evaluation package and the modifications made compared to the original CDIO Standards. The results are presented from a survey and an interview study directed to those programme managers who have applied CDIO Standards in the HSV evaluation. The questions in the survey are aimed at investigating respondents' views of the relevance, benefits, limitations and ease of use of the CDIO Standards. The questions are targeted at both the overall level – the body of standards – as well as at the level of single standards.

INTRODUCTION

The CDIO model is a model for engineering education that stresses that the product lifecycle of *Conceive – Design – Implement – Operate* (CDIO) should form the context for engineering education [1][2]. The process of designing a CDIO programme is guided by the CDIO Standards, a set of 12 principles that characterises this educational model, as well as general good practice in education [3]. So far, the CDIO Standards have been applied to a limited number and range of educational programmes, essentially collaborators in the CDIO Initiative [2].

In this article, the authors report on a large-scale application of the CDIO Standards. The context is the Swedish national evaluation of its *civilingenjör* engineering degree programmes. The authors first briefly outline the CDIO Standards, and describe why and how they have been used in the national evaluation. The results are next discussed of a survey and an interview study directed to those programme managers who have applied the CDIO Standards in the evaluation by the Swedish National Agency for Higher Education (HSV).

THE CDIO STANDARDS

The CDIO standards (see Table 1) define the essential characteristics of an engineering programme that has adopted the CDIO model [3]. The CDIO Standards serve as guidelines for educational programme reform and evaluation, create benchmarks and goals, and provide a framework for continuous improvement. The CDIO Standards address programme philosophy, curriculum development, design-build experiences and workspaces, new methods of teaching and learning, faculty development, plus assessment and evaluation. Seven are considered essential because they distinguish CDIO programmes from other educational reform initiatives (these

are marked by an asterisk (*) in Table 1) and five supplementary standards reflect best practice in engineering education.

The determination of a programme's progress towards the CDIO Standards is accomplished through self-evaluation. The fulfilment of each standard is measured on a five-level scale, which is used to rate the progress towards the planning and implementation of each CDIO Standard. The rubrics of the scale are stated in Table 2. This self-evaluation provides a tool for monitoring improvements via a series of evaluations where overall programme improvement can be made visible through an increase in the total score.

SWEDISH NATIONAL EVALUATION OF ENGINEERING PROGRAMMES

The Swedish National Agency for Higher Education (HSV) is the government agency responsible for evaluating the quality of university education in Sweden [4].

The purposes of the quality evaluations are as follows:

- Contribute to universities' internal work quality;
- Audit whether a particular educational programme meets the requirements specified in Swedish university law;
- Give information to prospective students;
- Inform the government of the quality of higher education;
- Give the public insight into the outcomes of investments made in the university sector.

An evaluation is a three-step process that consists of self-assessment, a site visit by an external review panel and a follow-up visit. The outcomes of the process include reports on all the university's programme, which may include the requirements of compulsory changes that, if not implemented, may lead to that university's right to offer the degree in question being revoked.

Table 1: The CDIO Standards.

Standard	Description
CDIO as Context*	Adoption of the principles of product and system lifecycle development and deployment — Conceiving, Designing, Implementing and Operating — as the context for engineering education
CDIO Syllabus Outcomes*	Specific, detailed learning outcomes for personal, interpersonal and product and system building skills, consistent with programme goals and validated by programme stakeholders
Integrated Curriculum*	A curriculum designed with mutually supporting disciplinary subjects with an explicit plan to integrate personal, interpersonal, and product and system building skills
Introduction to Engineering	An introductory course that provides the framework for engineering practice in product and system building, and introduces essential personal and interpersonal skills
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
CDIO Workspaces	Workspaces and laboratories that support and encourage hands-on learning of product and system building, disciplinary knowledge and social learning
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
Active Learning	Teaching and learning based on active experiential learning methods
Enhancement of Faculty CDIO Skills*	Actions that enhance faculty competences in personal, interpersonal, and product and system building skills
Enhancement of Faculty Teaching Skills	Actions that enhance faculty competences in providing integrated learning experiences in using active experiential learning methods and in assessing student learning
CDIO Skills Assessment*	Assessment of student learning in personal, interpersonal, and product and system building skills, as well as in disciplinary knowledge
CDIO Programme Evaluation	A system that evaluates programmes against these 12 standards, and provides feedback to students, faculty and other stakeholders for the purpose of continuous improvement

An evaluation of the *civilingenjör* engineering degree programmes took place in 2005. These programmes cover 4½ years (to be extended to five-year programmes in 2007), with integrated engineering programmes roughly equivalent to Master of Science or Diplom-Ingenieur degrees. There are about 100 such programmes in Sweden at roughly 10 different universities. The programmes range across all domains of science and engineering, including engineering physics, mechanical engineering, Information Technology (IT), industrial engineering and others.

In the *civilingenjör* programme evaluation, the self-assessment package contained about 20 university-level questions and about 50 programme-level questions. One example of a university-level question is *How does the university use knowledge about and experiences from graduated students in its educational planning?* [4]. An example of a programme-

level question is *Account for the considerations made when designing the programme* [4]. These questions are similar for programmes in all sectors. However, for this evaluation, the HSV also decided to add an overall programme assessment component to the questions [5].

Table 2: Rating scale used in CDIO Standards self-evaluation.

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

The purposes were as follows:

- Complement the responses to the basic questions in order to attain a more comprehensive, overall assessment of the university and programme;
- Give the external review panel an additional instrument for its analysis and evaluation;
- Provide the universities/programmes with an instrument that can be applied as a basis for future continuous improvement efforts.

The CDIO Standards and the associated self-assessment tools were chosen for this purpose. The application essentially followed that suggested in ref. [3]. However, a number of modifications were also made to adapt the standards to the context in that the standards were re-formulated to avoid the use of the acronym *CDIO*, while still keeping the corresponding content.

The programmes were also given an option to restate Standard One, thereby enabling them to replace the *product and system development* context with another one considered more fitting to their particular programme. Finally, there was no summary of a total score, the intention being to avoid any suspicion from universities or programmes that their total score would be used as a basis for some kind of ranking.

RESEARCH METHOD

In order to investigate the respondents' viewpoints of the CDIO Standards, a survey and an interview study was carried out. The survey questionnaire was divided into five parts.

- The first part covered background questions concerning what type of programme the respondent represents and previous knowledge of the CDIO Initiative.
- In the second and third parts, the respondents were asked to judge the ease of understanding, the ease of use, the relevance and the applicability of the overall CDIO Standards, as well as each individual CDIO Standard.
- The fourth part of the questionnaire covered the rating-scale.
- Finally, the respondents were given the opportunity to give general comments on positive and learning aspects of the CDIO Standards and also suggest improvements to the standards.

In the interviews, a set of open-ended questions were posed.

RESULTS

The response rate of the survey was approximately 30% and covered a broad spectrum of different engineering programmes. In some rare cases, the respondents did not give a complete answer, but there were roughly 30 observations for each statement. In addition, five interviews were carried out at two different universities. The interviews were recorded and transcribed verbatim.

Overall Questions

The survey contained 12 overall statements related to the entire set of CDIO Standards. For each statement, the respondents were asked to answer using a scale ranging from 1 to 5. Level 1 corresponds to *completely disagree*, while level 5 corresponds to *fully agree*. Figure 1 illustrates the mean value and standard deviation for each statement. The overall average rating was just above 3. For all statements, the standard deviations were found to be rather high. One reason for this is a small number of highly critical respondents gave *completely disagree* for all statements, also for those that were not CDIO-specific, but rather related to good educational practice in general. After discussion, it was decided not to exclude those data from the analysis. Due to the relatively small data set, those responses had a substantial influence on the standard deviation.

The highest ratings obtained were for the statements, *programme development guided by the standards improve the quality of the programme* and *evaluation does not require help from an expert*, respectively. Three statements fell somewhat below the average. These are the statements, *it is easy to make a programme evaluation with the standards and the rating scale*, *the standards simplify communication between different stakeholders in programme development* and *the evaluation results are easy to interpret*.

Questions per Standard

Four statements were made for each standard and the respondents were asked to answer using a scale ranging from 1 to 5. Level 1 corresponds to *completely disagree*, while level 5 corresponds to *fully agree*. These statements were as follows:

- The meaning of the standard is relevant for my programme;
- The description of the standard is easy to understand;
- Programme development using this standard improves the quality of the programme;
- It is easy to evaluate my programme with respect to this standard.

Relevance

The judgement of the relevance of the CDIO Standards for the programme was positive. Except for the slightly lower value for Standard 1, the mean values were all between 3.5 and 4.0. The data from the survey indicate clearly that the CDIO Standards state a number of principles that are relevant for many types of engineering programmes. However, the survey also shows that that especially Standard 1, ie CDIO as a context, caused problems concerning interpretation and relevance. There are approximately 100 engineering programmes in Sweden and they represent a broad spectrum of disciplines.

It should be noted that the modifications to the original CDIO Standards made in the HSV version included a provision for programmes to re-define Standard 1 to one that would be better suited to the programme's particular context.

Some Swedish engineering programmes have a very strong engineering identity and essentially sympathised with Standard 1. However, some of these programmes also indicated initial difficulties in translating Standard 1 into their context prior to accepting it. In some cases, this resulted in variants on Standard 1, which were close in content to the original, but more explicitly linked to a particular industry. The principle is to educate engineers to meet the needs of the construction industry, ie for planning, design, engineering, production, operations and maintenance.

Other Swedish engineering programmes formally lead to an engineering degree, but are strongly science-oriented, eg in physics or biology. It was not easy for some of the latter programmes to identify with the image of engineering that is reflected in the Standards.

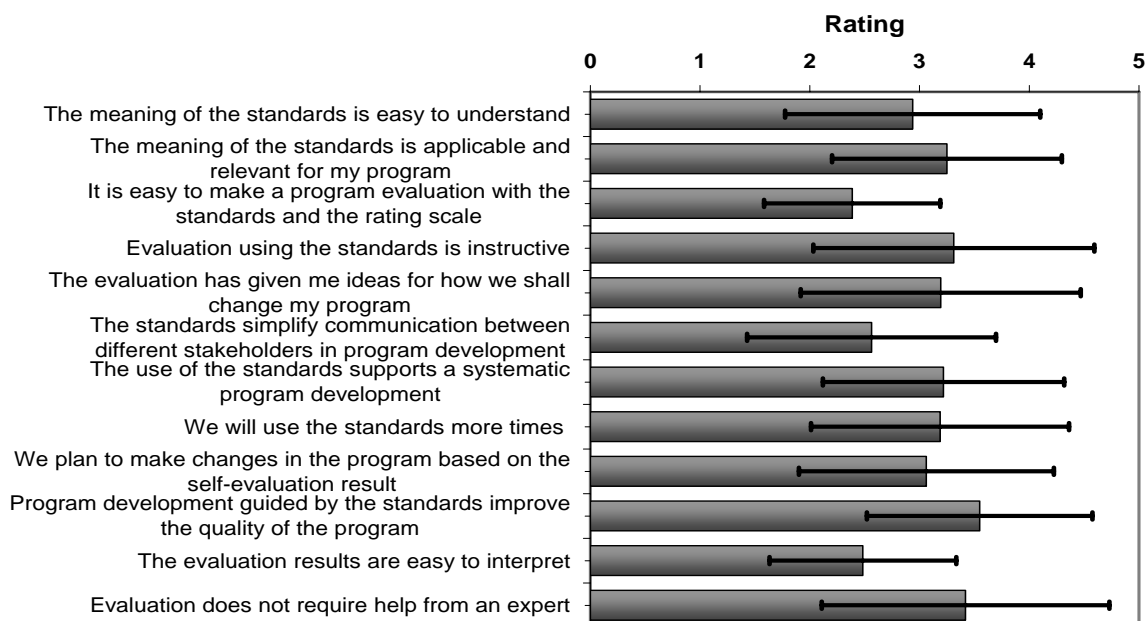


Figure 1: Average rating of the overall statements.

One of these programmes chose an alternative statement of Standard 1 to read as follows:

The X programme is strongly research-oriented and the students learn how to think, analyse, and solve problem in a research context rather than in the technical production context. The emphasis is more on knowledge production than on product production.

Importance for Programme Improvement

The third statement dealt with use of the CDIO Standards for programme improvement and the results of the rating were also positive, with mean values from 3.3 to 4.

When asked about what was positive about the standards, it was clear that the focus on systematic planning and documentation was perceived as new and useful. Managing the programme guided by the standards was seen as being superior compared to other *management* techniques that are hinted at, such as depending on chance or *fighting fires*.

Within the framework of a systematic approach, the respondents' further point to specific aspects that are supported, such as the advantage of having a clear set of guidelines to support decisions and follow-up. This is underlined by data from the survey, which strongly supports the notion that programme changes made according to the CDIO would improve programme quality (see Figure 1, statement 10).

The format of the self-evaluation, where the rating of each standard is backed with evidence and the need for action are identified, is described as providing a good agenda for implementing and following up on the change process.

Ease of Use for Programme Evaluation

The questionnaire also contained two statements concerning the rating scale used when evaluating a programme with the CDIO Standards. The statements read as follows:

- The rating scale has an adequate number of levels;
- It is easy to understand which value to select.

The mean values for the two statements were 3.6 and 2.5, respectively. This indicates that several respondents had difficulties evaluating the programme using the existing rating scale. One reason may be linked to the rating scale having two components: planning and implementation. Some respondents thus reported that it was difficult to choose the *right* value for a particular standard. Moreover, the rating scale was designed to give a premium on planning and documentation in order to create a solid base for the systematic development and discussion of programme plans. This is a key point in the CDIO model.

However, some respondents argued that there may be good implementations without explicit plans or documentation. In this sense, they seem to feel that they get a lower rating than they deserved. Consequently, many respondents emphasised the need to view the evaluation exercise as a support for quality enhancement processes, rather than quality assurance. The scale was not considered useful for rating a programme in absolute terms by comparing ratings.

Limitations

While the CDIO Standards provide a framework for capturing the domain-independent and *generic* competences expected from future engineers, the idea is also that the development of such skills goes hand-in-hand with the development of disciplinary knowledge. However, many respondents indicated concerns with the perceived focus on (only) personal, interpersonal, product and system development, and deployment skills. Their impression seems to be that the considerations of disciplinary knowledge and the connection to research are weak. The respondents indicated that they felt that disciplinary strengths and research perspective should be appreciated in the evaluation, rather than taken for granted. Especially when one of the purposes of the evaluation is to compare programmes from different universities, the respondents from universities with strong research environments wanted the evaluation to also reflect their traditional strengths. This points to the need to complement the CDIO Standards with other instruments in an overall evaluation and to make its role in the context clear.

CONCLUSIONS

In the Swedish national evaluation of engineering degree programmes, a modified version of the CDIO Standards was utilised to evaluate about 100 engineering programmes. The results indicate that the standards are relevant and applicable for a wider range of programmes than have been used, and that making changes towards implementing the standards would improve programme quality. The results also indicate that the standards' most important benefit is that they provide a basis for systematic programme development. Challenging issues when undertaking a CDIO Standards-based self-evaluation include interpreting Standard 1 within the context of the science and technological domain in question, and the proper use of the rating scale. There were also concerns regarding the fact that mainly the programme's actions to develop generic skills are visible in the evaluation, and this does not do justice to its attention to disciplinary knowledge and connections to research. This points to the need to complement the CDIO Standards with other instruments in an overall evaluation and to make its role in the context clear.

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