USING THE CDIO SYLLABUS IN FORMULATION OF PROGRAM GOALS – EXPERIENCES AND COMPARISONS

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ABSTRACT

This paper presents experiences and results from large scale and systematic use of the CDIO Syllabus for developing program goals and formulating learning outcomes at Linköping University (LiU), Sweden, and Technical University of Denmark (DTU). The approaches are based on the use of tools for program design such as ITU-matrices and skill progression matrices. During the process local adaptations of the Syllabus have been made in order to meet regulations by authorities in higher education as well as to cover programs in related areas as natural sciences. The experiences are that the CDIO Syllabus is a very useful tool in this process and that the way of organizing the management of the education programs is important for success as well as support from students, faculty members and stakeholders.

KEYWORDS

Program goal, curriculum design, learning outcomes, ITU-matrix, skill progression matrix

INTRODUCTION AND BACKGROUND

The CDIO model for development of engineering education puts a strong emphasis on formulation of program goals and learning outcomes, as seen in Standards 2 and 3 of the CDIO Standards [1]. A lot of effort has been spent on this topic since the start of the CDIO Initiative, a number of results have been presented; see e.g. [2] – [7], and several documents and tools for this purpose have been developed. The development of program goals and specification of learning outcomes is also a key component in the Bologna process [8], which requires that programs and courses have clear and comparable learning outcomes. In addition several other stakeholders can benefit from such documents, like e.g. students, faculty members, industry, and governmental institutions. The purpose of the paper is to present experiences from large scale development of program goals and learning outcomes using the CDIO Syllabus and related tools. The paper will present experiences from Linköping University (LiU), Sweden, and Technical University of Denmark (DTU), and discuss similarities and differences in the approaches.

There are many factors that are essential for making such a development process successful, and some of these factors will be discussed in the paper. This includes a strong and documented support from the university leadership, as well as interest and engagement from faculty members and students. The development process has hence been a combination of a top-down and a bottom-up process. It has been found necessary and useful to extend and develop some of the original documents and tools. For example, one reason for this has been the ambition to cover various different disciplines in engineering and also non-engineering programs offered at the university, like e.g. natural sciences. Another reason has been to meet the national requirements concerning sustainable development. The process has also been useful in clarifying the difference in objectives of a bachelor and master degree of engineering, respectively.

The development processes at LiU and DTU have both similarities and differences, and one of the aims of this paper is to present and discuss the two different approaches. For example has systematic introduction of the CDIO concept been introduced in renewed programs at DTU from year one and at LiU at several educational levels at the same time. Another notable difference is the use of the CDIO tools to express progression within the programs.

ORGANIZATION

In this section the organization of studies and programs will be shortly presented in order to present a framework of comparison and discussion for the implementing processes at LiU and DTU. The engineering education at LiU is organized with Program Boards which consist of faculty members, representatives from industries as well as student representatives and are organized in the following subject areas: Computer Science and Engineering and Media Technology (DM), Electrical Engineering, Physics and Mathematics (EF), Industrial Engineering, Management, and Logistics (IL), Chemistry, Biology and Biotechnology (KB) and Mechanical Engineering and Design (MD). All Program Boards administer programs at different educational levels, like Bachelor Programs and Master Programs in Engineering, as well as programs in related areas like natural science, computer science, mathematics and industrial management. The majority of the students follow five years engineering programs, and most of the efforts reported here are devoted to this category of programs. The Program Board has an overall responsibility for the programs which includes strategic considerations, evaluation and quality assurance, and continuous improvement of the programs. This means that the Board also decides on the Syllabus, Curriculum and Course Plans for each program and the board is advisory to the Dean and the Faculty Board on issues within the range of the Program Board. All education programs undergo a yearly revision process in which program goals and learning outcomes of the individual courses are reviewed.

The Chairmen and the administrative responsible Directors of Studies of the five Program Boards meet the faculty management staff, including the Dean, and students representing the Student Union regularly once a week to discuss common questions covering undergraduate studies as well as related topics. The purpose of the group, which is denoted LGU, is to provide a platform for discussion of all relevant aspects of undergraduate studies at the faculty of Engineering and Sciences (see Figure 1). Agreements reached in LGU are advisory to the Dean and to the Faculty Board.

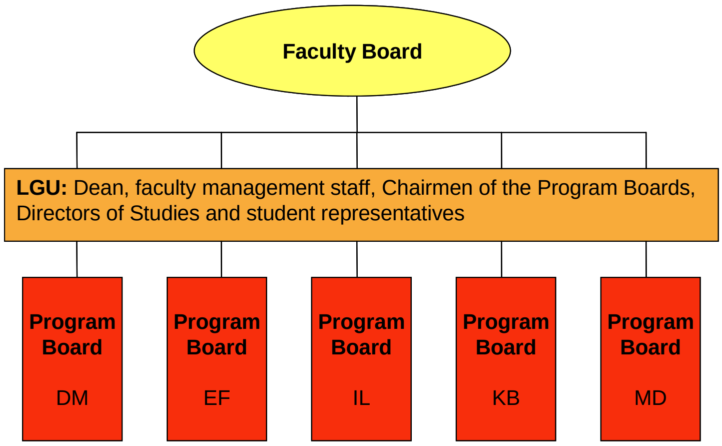

Figure 1: Organization at the Faculty of Engineering and Sciences at LiU.

The Program Boards order suitable courses from the different departments, and there is a discussion about course aims and contents between the Program Board, the department, and the examiner. However, the ideas about using the CDIO model for development of engineering education are not restricted only to a certain course but also to a whole program which has requested other approaches to engage the faculty staff members. The changes expected by the Bologna declaration was suitable in time for rethinking our engineering education and the CDIO model was found very helpful in development of program goals and learning outcomes. All members of the faculty staff were engaged in rewriting all Course Plans and workshops were arranged by staff at the Dean's office.

DTU educates engineers in two separate streams of education: The Bachelor of Engineering (B ENG) is a 3½ year program, and qualifies the student to go directly into industry to jobs in e.g. production units, project management or control and support functions. The Master of Science in Engineering (MSC ENG) is a 2 year program, which follows the 3 year Bachelor of Science in Engineering Program (BSC ENG). The student graduating with a Master's degree may continue to research as a PhD student or go to industry. Hence, DTU has adapted fully to the Bologna system. For each of the study programs at DTU the Dean has appointed a program coordinator who in co-operation with the study board undertakes the practical organization of teaching and assessments forming part of the exams. The program coordinator has a supporting work group with representatives of teachers and students and this work group has been very active in the process of changing curriculum and implementing CDIO at DTU. There are a number of departments at DTU and each department has a study board. Most study programs comprise of courses from several institutes and several study boards are involved in each program. Thus, the program coordinators play an important role. Every department has an Advisory Board consisting of representatives from industries which eventually will employ the newly-educated engineers. The Advisory Boards comment on the development of existing and new study programs and DTU uses the feed back for adjustments to ensure that the engineers get the right qualifications. Twice a year DTU invites all teachers and program coordinators to a seminar where ideas, challenges and best practises from teaching at the CDIO courses are discussed. This commits the teachers to maintain the courses. Several times a year all the program coordinators meet with the dean to discuss challenges and exchange ideas with each other. The program coordinators have continuous meetings with their supporting work group of teachers and students from the program. Everyone involved in the CDIO programs at DTU are encouraged to take part in the international CDIO conferences to get new inspiration and share best practices with people from all over the world. The students are continuously asked about their opinion about courses etc. in different kinds of evaluations. The results of these evaluations are taken note of by teachers and program coordinators and are incorporated in the development of the programs.

CDIO IMPLEMENTATION

Linköping University is one of the four original collaborators in the CDIO Initiative. Most of the efforts during the first years were spent on the engineering program Applied Physics and Electrical Engineering, and brief summaries of the outcomes of the development of this program can be found in [12] and [13]. The CDIO ideas gradually spread within LiU and were adopted by other programs and in other disciplines as reported in [14] and [15]. In 2006, the Board of the Faculty of Engineering and Sciences decided, as a part of the adoption of the Bologna process, that all program goals and learning outcomes should be based on the CDIO Syllabus. A condition for progress and success in this work has been a clear supportive statement from the faculty management staff, an organization that can follow up the agreements, as well as a clear commitment from many members of the faculty staff to engage in the development process and a positive feedback from the engineering students. The statement from the Board of the Faculty of Engineering and Sciences makes a framework for the five Program Boards, each covering several programs in related disciplines. A prerequisite for success is also the attitude about these issues amongst the students. The Student Union has been supportive in the process and the evaluations from students have been very positive. A survey amongst alumni from nine different engineering programs representing different disciplines clearly supports the effort to strengthen the engineering identity [11]. Parts of the CDIO model have also been adopted at other universities (in addition to the universities being CDIO collaborators) in Sweden in various ways. One of the most important factors was the use of the CDIO Standards in the national evaluation (of five years engineering degree programs) that was carried out by the Swedish National Agency for Higher Education. Some observations concerning the outcomes of the use of the CDIO Standards in this evaluation are presented in [18].

At DTU it was a management decision to implement the CDIO principles consecutively – starting in 2008 with the first year courses, and completing the process in 2011 for the full bachelor of engineering program. A work group with the Dean of Education, representatives from the students, teachers and program coordinators from the involved programs and the administration discussed how DTU should adapt to CDIO and produced a detailed plan of action [17]. The plan of action has been the central document used by everyone involved in the implementation process at DTU. Traditionally, the BSC ENG and MSC ENG programs at DTU contain a very high degree of freedom for the students to compose study profiles and elective courses. The B ENG programs are more defined with respect to the course work and practical work the students have to fulfil. At DTU the B ENG programs are now being reformed along the CDIO philosophy. Until now CDIO has been implemented in six programs covering Mechanical, Chemical and Biochemical, Civil, Architectural, Electrical and IT Engineering.

PROCESSES AND TOOLS FOR EDUCATIONAL PROGRAM DESIGN

Adaption of the CDIO Syllabus

The ultimate goal of the process is to develop documents that in a clear way defines the goals of the program and shows how the program goals are connected to the learning outcomes in the individual courses and the examination. The process of formulating program goals has two very important components. First, similar to all types of development projects, it is necessary to have a systematic approach, and second, it is necessary to have suitable tools that support the process. A complete description of the CDIO Syllabus can be found via [9], and the main sections can be seen in Figure 2. We will here discuss the modifications of CDIO Syllabus that have been carried out at LiU and DTU respectively, but other examples can also be found as for example in [19].

In the Swedish system for higher education the overall most important document is Högskoleförordningen (The Degree Ordinance) [10], which specifies expected knowledge and skills for various types of educations, including engineering programs. The Degree Ordinance can however be mapped to the CDIO Syllabus, see [6], and hence the Board of the Faculty of Engineering and Science 2006 decided that learning outcomes and program goals should be based on the CDIO Syllabus. In Denmark, the overall control with the B ENG programs is held by the Danish Ministry of Education. Educational programs are regularly evaluated and accredited by the National Agencies, ACE/EVA. The implementation of CDIO at DTU's B ENG programs has been a great help in preparing the whole organization for planned accreditations in the future.

The CDIO Syllabus represents a long list of desired knowledge and skills and it has been used both at DTU and LiU as a tool for educational design. The extensive use of the CDIO Syllabus within LiU has motivated some extensions of the original version of the Syllabus.

- The Degree Ordinance puts strong emphasis on sustainable development, and this is expressed by the formulation "… including economical, social and ecological sustainable development". These aspects are naturally covered by Section 4.1 in the Syllabus, but in order to make this requirement more visible the quoted formulation from the Degree Ordinance has been included in the local version of the Syllabus.
- The Industrial Engineering and Management program is one of the biggest engineering programs at LiU. The program has specializations in for example marketing, logistics and financing. In the program plan it is expressed that one of the main goals for the engineers graduating from this program is to be able to be leading in the process of implementing the outcome of the engineering work into business activities. This can be seen as an extension of the scope of the role of an engineer

as it is expressed in the original version of the Syllabus, and to stress this fact the title of Section 4 of the Syllabus has been modified accordingly.

- The Faculty of Engineering and Science has also a number of educational programs in natural sciences (physics, chemistry, biology, and mathematics). For these programs, the product development and system building context is less appropriate, and for this purpose a modified version of Section 4 has been developed with this type of programs in mind. The product development framework is there replaced with a more research oriented one.

At DTU the Syllabus was simplified to a version (nick-named the DTU Syllabus) which was simpler and hence easier to use for faculty members unfamiliar with the CDIO principles. The most detailed level of skills in the original syllabus has been left out and the DTU Syllabus was concentrated to a two-sheet version. The DTU Syllabus is characterized by being shorter (less detailed skills), more operational (operational skills according to Blooms taxonomy), not only designed for mechanical/ design engineering fields (the same syllabus need to fit all B ENG programs at DTU), and adapted to a B ENG program (some skills were too advanced and were left out)

The process for educational program design

The development process at LiU can be described as a combination of a top-down and a bottom-up process. The bottom-up process was described in some detail in [5], and the aim here is to concentrate on the top-down process and how the processes can be linked together. The top-down approach starts from the management level, including the Board of the Faculty of Engineering and Science and the Dean. Closely connected to the Board is LGU, see above, consisting of the Chairman and the Director of Studies from the five Program Boards, student representatives, and the Dean.

The starting point of the top-down process was to describe, in a few sentences, the properties and attributes that should be characteristic for an engineer graduating from a five years engineering program at LiU. The outcome of this step was summarized under the heading “The LiU Engineer”, and organized according to the four sections of the CDIO Syllabus. The next step in the top-down process was to formulate the program goals in more detail, and also this was done according to the structure of the CDIO Syllabus. Since Sections 2 – 4 of the Syllabus are independent of the subject area of a particular program the program goals in these sections should be applicable to all engineering programs. In order to distribute the efforts the task to formulate goals for these sections was distributed among the Program Boards. In addition to the shared work load this meant that all people involved in the process were motivated to study the Syllabus in detail. The outcomes of this step were presented and discussed during a workshop for all members of LGU, and the formulations were revised in order to obtain coherent formulations of the program goal for Sections 2 – 4. Even though the first section of the Syllabus is closely connected to the subjects of a particular education program, it also for this section possible to express goals that are common for all programs. For example, mathematics plays an important role for all engineering programs, and LiU has high ambitions concerning the contents of mathematics in the engineering education. Therefore, it was agreed that all programs should have similar formulations of the mathematics related goals. In general it has been found important and useful in this process to include also Section 1 of the Syllabus, since it defines the basis of the program in terms of mathematics, natural sciences and engineering topics.

In order to be able to quantify the progression of knowledge in various areas Section 1 is a natural starting point.

It is important to stress that it is not only the goal document itself that is a valuable outcome of the goal formulation. Also the process itself, in the form it has been carried out, has been valuable, since it has generated fruitful discussions about the common vision and ambitions of the engineering education at LiU, but also clarified similarities and differences of the different programs.

For each of the study programs DTU has formulated one sheet that sums up the competences imparted. For the B ENG programs the competences are split up in general qualifications achieved by all B ENG's at DTU and specific skills obtained from the individual program. All the general qualifications can be mapped to Syllabus categories 2-4. DTU has attempted to homogenize categories 2, 3 and 4 between the study programs in different fields but it is not necessarily easy or straightforward as there are variations in the required skills in the different industries e.g. the industrial expectations to written communication might differ in civil and chemical engineering.

As at LiU mathematics at DTU is a highly prioritized field in all engineering programs. No matter which branch of engineering the students choose they need to gain a certain level of mathematics. The Department of Mathematics at DTU has designed one common course that fits all the B ENG programs. This has the advantage that it provides all the students with the same mathematical basis although some programs e.g. IT and Chemical Engineering request the possibility of different mathematics. This is an ongoing discussion.

The bottom-up process is described in [5], and only the main aspects will be discussed here. The process starts at the course level and involves topics like the expected learning outcomes of the course, the organization of the learning activities, the examination etc. In the Swedish system the official document for a course is the Course Plan. This is a mandatory document and specifies the learning outcomes, the examination and grading, literature etc, and all Course Plans are formally approved by the Program Board. The Course Plan has a more or less fixed structure, and for practical reasons additional information is collected in a Course Information administrated by the faculty member responsible for the course. In addition to the Course Plan the Board of the Faculty of Engineering and Science has decided that each Course Plan should be complemented by a so called ITU-matrix. The purpose of an ITU-matrix, introduced in [5], is to describe the course in relation to the CDIO Syllabus. In practice this means that, for each individual course, the faculty member responsible for that course is supposed to fill in a matrix, of the type shown in Figure 2. In the ITU-matrix, the I-column represents topics that are introduced in the course, but not subject to examination. The T-column represents knowledge and skills that are taught in the course and also subject to examination. Finally, the U-column represents knowledge and skills that have been acquired in previous courses and are considered to be pre-requisites. These will of course be included indirectly in the examination, like e.g. mathematics in an engineering course. In order to keep the effort at a reasonable level, it was decided to work at the X.Y level of the Syllabus. In the process of filling in a matrix the complete Syllabus, i.e. also lower levels (X.Y.Z), can be used in order to find examples of what a particular level represents.

TSRT19, Automatic Control I		I (Introduce)	T (Teach)	U (Utilize)	Comments
1	TECHNICAL KNOWLEDGE AND REASONING				
1.1	KNOWLEDGE OF UNDERLYING SCIENCES			X	calculus, algebra, physics
1.2	CORE ENGINEERING FUNDAMENTAL KNOWLEDGE	X	X		analysis and design of control systems
1.3	ADVANCED ENGINEERING FUNDAMENTAL KNOWLEDGE				
2	PERSONAL AND PROFESSIONAL SKILLS AND ATTRIBUTES				
2.1	ENGINEERING REASONING AND PROBLEM SOLVING	X	X		modeling of systems and signals
2.2	EXPERIMENTATION AND KNOWLEDGE DISCOVERY		X	X	experimentation using laboratory processes
2.3	SYSTEM THINKING	X	X		general thinking throughout the course
2.4	PERSONAL SKILLS AND ATTITUDES			X	individual work during problem solving
2.5	PROFESSIONAL SKILLS AND ATTITUDES				
3	INTERPERSONAL SKILLS: TEAMWORK AND COMMUNICATION				
3.1	TEAMWORK			X	laboratory exercises in groups of 2
3.2	COMMUNICATION			X	written report
3.3	COMMUNICATION IN FOREIGN LANGUAGES	X		X	introduces English control vocabulary
4	CONCEIVING, DESIGNING, IMPLEMENTING AND OPERATING SYSTEMS IN THE ENTERPRISE AND SOCIETAL CONTEXT				
4.1	EXTERNAL AND SOCIETAL CONTEXT	X			the role of control in systems, products
					and processes
4.2	ENTERPRISE AND BUSINESS CONTEXT				
4.3	CONCEIVING AND ENGINEERING SYSTEMS	X	X		fundamental limitations in control systems
4.4	DESIGNING	X	X		design of control systems
4.5	IMPLEMENTING	X			implementation on laboratory processes
4.6	OPERATING				

Figure 2: Example of a course level ITU-matrix from LiU.

In the second step of the bottom-up process, the course based ITU-matrices are put together to form ITU-matrices for entire programs and specializations within programs. Further aspects of this step are discussed in [5]. An example of such a matrix is shown in Figure 3.

Mechatronics	1.1	1.2	1.3	2.1	2.2	2.3	2.4	2.5	3.1	3.2	3.3	4.1	4.2	4.3	4.4	4.5	4.6
Analytical mechanics	U		T	TU		T	T		U	U	U						
Modeling and simulation	U	TU	IT	T	TU	TU	U		U	U		I		IT		IT	
Automotive control systems	U	U	T	U	U	TU		U		U		T		TU	TU	TU	
Applied therm. and fluid dynamics	U	TU		T			I		I	I							
Digital signal processing	U	TU	IT	T	TU	TU	U					I	I	IT		IT	I
Control theory	U	U	T	T	TU	TU	U		U	U		I		T	T	I	
Real time and concurrent progr.	U	TU	I	T	U	T	T		U	U	U			T	T		
Project - Applied mathematics	TU			TU	TU		TU	TU	U	IT							
Automatic control project course	U	U	TU	TU	U	TU	TU	TU	TU	TU	U	I	I	TU	TU	TU	I
Flight dynamics	ITU	TU					TU			U							
Multi body dynamics and robotics	U		T	T					I	U							
Computational fluid dynamics	ITU			T	T					U							
Vehicle dynamics and control	U	U	T	T		T			U	U							
Aerodynamics	ITU	TU		T													
Diagnosis and supervision	U	U	T	T		T				U							
Digital control	U	IT		IT	TU	IT	U		U	TU		I		IT	IT	I	

Figure 3: Example of a program level ITU-matrix from LiU.

At DTU, the starting point in the bottom-up process was that every teacher responsible for a course formulated the learning outcome of the course in 8-12 bullets. The bullets are also used as measuring points for the exams so the students get the highest grade if they demonstrate that they have fully met all the learning outcomes. After formulating the learning outcomes for the courses, the program coordinators for every B ENG program at DTU arranged discussion meetings with all teachers teaching at the first 4 compulsory semesters. At these meetings, the Syllabus skills were mapped against the compulsory courses in a Skill Progression Matrix in order to get an overview of how and whether the skills in syllabus were present in the pre-CDIO programs. The teachers had to judge which skills and to which level of Bloom's taxonomy, they brought the students in their course. The results from these meetings constituted the basis for restructuring the programs when implementing CDIO. After the implementation of CDIO at DTU, all the courses at the different study programs have been mapped again in a new Skill Progression Matrix (Figure 4). The learning outcomes from the individual courses all together can now be mapped against the competences imparted for the full study program and the skills in the DTU Syllabus.

Describing progression

Characterizing and quantifying knowledge and skills is a complex task with many dimensions and, to the best of our knowledge, there is no universal and generally accepted way of dealing with this task. The aim of this part of the paper is to present and discuss the approaches that have been used within The Faculty of Engineering and Sciences at LiU and within DTU, rather than discussing this vast topic in general. As mentioned earlier all program goals and learning outcomes are based on the sections of the CDIO Syllabus, which has been found to be a suitable way to define a structure for knowledge and skills. An alternative is of course, the structure offered by the Dublin Descriptors, which uses the structure: *Knowledge and understanding, Applying knowledge and understanding, Making judgements, Communication skills, and Learning skills*.

To describe progression within a subject or an education is an important issue, both in general but also implied by the Bologna process. Progression of knowledge and skills in engineering education involves many aspects and dimensions, and it is a challenging task to describe progression in all its dimensions. The sequence Introduce-Teach-Utilize that is used in the ITU-matrices at LiU represents one way of quantifying progression within the topics defined by the structure of the CDIO Syllabus. Considering a sequence of courses within a particular area one finds that the marks in the ITU-columns shift from left to right, i.e. a course early in the education has more marks in the I-column and a related course later in the education has more marks in the right column. Another feature that can be seen is that courses in the early years often have fewer sections of the Syllabus marked, while courses in the later years have more sections marked. This is most evident in project courses and courses with extensive laboratory exercises, in which most of the section of the Syllabus are relevant. DTU has expressed the progression in the study programs by integrating Blooms taxonomy in the Skill Progression Matrix (Figure 4). The interpretation of the levels is given in Figure 5. The courses given in the first four compulsory semesters are mapped against the skills in DTU Syllabus category 2-4. The numbers and colours in the cells reflect to which level the students are taught in the given course e.g. 1: Knowledge, 2: Comprehension, 3: Application, 4: Analysis and 5: Synthesis. As seen in Figure 4 no skills are taught to level 5 as it is a B ENG program which never reaches the level of Synthesis.

DTU Syllabus	*2.1*	*2.2*	*2.3*	*2.4*	*2.5*	*3.1*	*3.2*	*3.3*	*4.1*	*4.2*	*4.3*	*4.4*	*4.5*	*4.6*
Calculus and algebra 1	1						1	1				1		
Structural elements and their function (1)	2		2			1	1/2	1				1		
Urban Planning and Design	2		2	2		1	1/2	1				1		
CAD, sketching and 3D-modelling						1						1		
Theory and Practice of Architectural Engineering	2		2	2	2	1	1/2					1		
Material science		2					1/2	1				1		
CDIO project		3	2	2		1								
Calculus and algebra 2	2						2	2						
CAD, sketching and 3D-modelling	2					2								
Theory and Practice of Architectural Engineering		3		2	2	3	2					2		
Structural elements and their function (2)	3	3	2			3	2	2			1	2		
House Building and Building Design	2/3	3	2	2	2	2/3	2	2	1		1	2	1	
CDIO project		3	2	2								2		
Physics							3	3				3		
Structural design and design models (1)	4		3		2		3		2			3		
Urban context & large scale structures	4		3	4		3/4	3					3		
Systematical planning with CAD-system and Visualization						3							1	
Background for architectural engineering	4			4	3	4	3					3		
Basic building design: indoor environment, services and energy	4						3	3				3		
Geometry	4						4	4						
CDIO project	4		3		2	3/4					2	3		
Systematical planning with CAD-system and Visualization	4						4							
Background for architectural engineering			3	4	3	4	4					4		
Structural Design and Models (2)	4					4	4	4	2			4		
A Concert hall	4		3	4		4	4					4		1
Basic building design: indoor environment, services and energy	4		3		3	4	4	4				4		1
CDIO project	4		3		3	4					2	4		

Figure 4: Example of a skill progression matrix from DTU.

Bloom level	0	1	2	3	4	5
Color						
		Knowledge	Comprehension	Application	Analysis	Synthesis

Figure 5: Interpretation of the levels in the skill progression matrix in Figure 4.

The different colours help the visualisation of the progression. As at a geographical map the blue colour indicates “deep water” and the red colour “high level”. It guarantees that all material is introduced and taught before being used. The progression and repeated use of taught material (at different levels) in the B ENG programs at DTU is also ensured by securing continuous communication among the teachers teaching at the same semester as a supplement to the work carried out by the group of teachers and students that supports the program coordinator as described earlier in this paper.

DEVELOPMENT AND MAINTENANCE

One result of the efforts is a mutual vision of “The LiU Engineer” for all engineering programs. The program goal development aims to fulfil this vision. It is a risk that this ambition tends to raise the demands on the student above reasonable requirements and, therefore, it is necessary to get feedback from stakeholders, alumni and teachers to continue the development process. Do all students actually meet these demands? Another question raised is to which extent every part of the CDIO Syllabus has to be achieved within the different programs with different profiles. This is a present work which has to be carried out carefully since it should reflect the essence of the program.

Since LiU has extended the CDIO Syllabus to manifest special demands from Högskoleförordningen (The Degree Ordinance), the relevance of the Syllabus continuously must be updated with new demands of this dignity. To clear the differences between the engineering programs and the related programs in natural sciences the extended version of the CDIO Syllabus has been used. This has turned out to be useful to describe these differences in a systematic way and starts to be spread nationwide.

The Swedish government discusses the introduction of a new economic resource system partly based on achieved quality, where goal fulfilment has been discussed as one possible condition, and in this respect, the CDIO model is an important tool to prove the outcome. This implies that further adjustments of the method have to be made. Furthermore, there is also an ongoing discussion in Sweden about introducing an accreditation system and it will be necessary that the local system is consistent with this. The EUR-ACE framework for the Accreditation of Engineering Programmes, for instance, has defined six program outcomes that must be fulfilled for accreditation including Knowledge and Understanding, Engineering Analysis, Design and Practice as well as Investigations and Transferable Skills [16]. Even these goals are defined with progression from the bachelor level to the master level and cover aspects of theoretical knowledge, practical skills as well as personal and interpersonal skills. Depending on the accreditation system that is decided on, the local program goals have to adapt.

Next step in the process is to assure the progression of the examination and form for examination connected to program and course goals. A feedback system connected to the thesis work based on the students own reflection on the achieved knowledge and skills is prepared and introduced in the near future at LiU.

CONCLUSIONS AND LESSONS LEARNED

Experiences and results from large scale and systematic use of the CDIO Syllabus for developing program goals and formulating learning outcomes at Linköping University (LiU), Sweden, and Technical University of Denmark (DTU) have been presented. The approaches have based on the use of tools for program design such as ITU-matrices and skill progression matrices. During the process local adaptations of the Syllabus have been made in order to meet regulations by authorities in higher education as well as to cover programs in related areas as natural sciences. The experiences are that the CDIO Syllabus is a very useful tool in this process and that the way of organizing the management of the education programs is important for success as well as support from students, faculty members and stakeholders. The main lesson learned is that the large scale adoption of the CDIO model is a multi-faceted process that requires mutual engagement and respect for other adopters´ views. This takes more time than expected. To achieve the desired outcome all groups involved should be able to work concentrated during continuous periods of time instead of shorter time slots. This since new adopters of the ideas sometimes find the concept difficult to accommodate and need the support and discussions from a team of faculty members. Due to new demands from different stakeholders the conditions for the CDIO development process changed during implementation. This made it not possible to say when the work actually was done. It can also be noted that the process is helped if respected persons from outside the own organization, i.e. other universities or industry, regard the initiative as a successful concept and declares a willingness to adopt it.

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