Applying an innovative educational program for the education of today’s engineers

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Abstract. Engineers require a broad spectrum of knowledge and skills: basic skills in mathematics and physics, skills and competencies within the major subject area as well as more general knowledge about business and enterprise contexts, society regulations and understanding of the future professions’ characteristics. In addition, social, intercultural, analytical and managing competencies are desired. The CDIO educational program was initiated as a means to come closer to practice and to assure the training of engineering skills that are required of today’s engineers. CDIO is short for Conceive-Design-Implement-Operate and describes the full life cycle understanding of a system or asset that engineering students should reach during education. The CDIO initiative is formulated in a program consisting of two important documents: the CDIO standards and the CDIO syllabus. The standards describe a holistic approach on education, from knowledge and skills to be trained, how to train and assess them, to how to develop the teaching staff and the work places for enabling the goals. The specific knowledge and skills to be achieved are accounted for in the syllabus. In this paper we share our more than 15 years of experiences in problem and project based learning from the perspective of the CDIO standards. For each standard, examples of how to set up the education and overcome challenges connected to the standard are given. The paper concludes with recommendations to others wishing to work toward problem and real-life based education without compromising the requirements of a scientific approach.

1. Introduction
Engineers require a broad spectrum of knowledge and skills. A sound knowledge foundation is based on basic skills in mathematics and physics, skills and competencies within the major subject area as well as more general knowledge about business and enterprise contexts, society regulations and understanding of the future professions’ characteristics. But requiring these skills during the education does not guarantee the employability of the graduated student. The generic, or transferrable, skills are pointed out as important in achieving a full spectrum of capabilities for the modern engineers [1] and [2]. These skills comprise communication and team work skills, problem solving and critical thinking, time planning, flexibility and independence in the learning process, to mention a few.

It is not enough to add a single course in project management and communication in order to train these abilities, for instance as an independent work in the end of the education. Instead, the total education program should be integrating the generic skills’ training as a means to learn the basic technical and engineering subjects. This paper describes one attempt in achieving an integrated curriculum for a three-year industrial engineering program with specialization in maintenance
management. The curriculum is influenced by the international engineering education initiative CDIO (Conceive – Design – Implement – Operate), which was developed by the Royal Institute of Technology (KTH), Chalmers and Lindköping University (LiU) in Sweden and Massachusetts Institute of Technology (MIT) in the US in the 2000s.

The paper is outlined as follows: In the next section the engineering skills and employability is discussed. In section 3 the CDIO initiative is described. The education within Total Quality Maintenance at Linnaeus University is introduced in section 4, and a more detailed description of the developed engineering program in industrial engineering with specialization in maintenance management is given in the following. This is the program where the CDIO initiative is currently implemented. Examples of how to work with CDIO will be given based on this ongoing work. The paper finishes with some concluding remarks on the usefulness of CDIO for the creation of an innovative educational program.

2. Engineering skills and employability

Yorke och Knight [3] interprets employability as a graduate’s (or other awardee’s) suitability for appropriate employment. This ability does not automatically give a graduated student employment though, because of various external factors such as the economical situation, but plays an important part in the context. Yorke and Knight have in the USEM model tried to explain how different competencies correlates and how these skills contributes to the employability of a student [2]. USEM stands for Understanding, Skills, Efficacy benefits and Metacognition, see figure 1. Understanding refers to deep knowledge gained in education within a specific subject area. Skills are generic skills that are not connected to a specific subject, but could be utilized in different contexts. Examples of generic skills are information handling, team working, communication and critical thinking. The Efficacy is intrapersonal abilities and self awareness. Metacognition stands for higher reflective abilities and strategic thinking.

In [1] a panel of 16 engineering professors from different US schools was asked to identify generic skills that were important in engineering education. The study found that professors rate students’ interpersonal, communication, and work ethic competencies as desired when entering into postsecondary engineering and technology programs.

In [2] results from a survey of the apprehended future need of competencies in Swedish industry are reported. The study was commissioned by the confederation of Swedish enterprise and the national

![Figure 1. The USEM model, [3] in [2].](image_url)
research founding body KK-stiftelsen. From this survey, six categories of competencies were addresses:

- Basic competencies (Reading, writing, calculating)
- Social competencies (Empathic skills, cooperation, communication)
- Intercultural competencies (Language skills, open mind towards other cultures)
- Analytical competencies (Independent problem solving and critical reasoning)
- Entrepreneurial competencies (Ability to identify and realize opportunities, skills in entrepreneurship)
- Managing competencies (Organizing and managing people to meet business goals)

The surveys in [1] and [2] both confirm that broad spectra of knowledge and skills are required of the engineer of today. This is what the Conceive-Implement-Design-Operate (CDIO) initiative also propagates.

3. The CDIO initiative

The CDIO initiative is introduced to the reader here. A brief description of the initiative and the key concepts are addressed.

3.1. Background

The CDIO initiative is a world wide program with the aim to create the next generation of leading engineers [4] and [5]. The CDIO original developers (Chalmers, KTH, LiU and MIT), the early collaborators (Technical University of Denmark, Queen's Belfast and Ontario, The US Naval Academy; and the University of Pretoria) and one representative of each of the CDIO Regional Centers form the CDIO council. The CDIO Initiative was developed in cooperation with academics, industry, engineers, and students. More than 50 collaborating institutions in over 25 countries forms the network today. The aim is to offer a shared basis for creating the next generation of engineers. It is a non-profit organization which creates a global network of engineering education institutions, and the participation is free for all.

CDIO has developed a list of competencies and skills which form a curriculum of the future engineer, see table 1 and section 3.2. CDIO is currently working to incorporate and assure these skills in engineering education.

Table 1. Competencies of an engineer.

| 1. Technical knowledge and reasoning | 1.1 Knowledge of underlying sciences |
|--------------------------------------|-------------------------------------|
| 1.2 Core engineering fundamental knowledge |
| 1.3 Advanced engineering fundamental knowledge |
| 2. Personal and professional skills and attributes | 2.1 Engineering reasoning and problem solving |
| 2.2 Experimentation and knowledge discovery |
| 2.3 System thinking |
| 2.4 Personal skills and attributes |
| 2.5 Professional skills and attitudes |
| 3. Interpersonal skills: teamwork and communication | 3.1 Teamwork |
| 3.2 Communications |
| 3.3 Communication in foreign languages |
| 4. Conceiving, designing, implementing and operating systems in the enterprise and societal context | 4.1 External and societal context |
| 4.2 Enterprise and business context |
| 4.3 Conceiving and engineering systems |
| 4.4 Designing |
| 4.5 Implementing |
| 4.5 Operating |
3.2. The CDIO syllabus
The aim with the syllabus is to create a complete, consistent and generalizable set of competencies that forms the goals of undergraduate engineering education. The original version of the syllabus, of which the main topics are listed in table 1 was created in 2001. For the categories two to four the level of competencies are specified in a hierarchical form down to three levels, while the first category is specified in two levels. In the table only two out of three levels are accounted for all categories. Recently a new version of the syllabus has been launched. In this paper we use the original version because the education program example is based on the original version. Another reason is that the updates are not fundamentally changing the original concept; they rather elucidate the competencies.

The first three categories of skills form the basis for the fourth category. In order to approach the engineering profession with a life cycle perspective, expressed as skills in conceiving, designing, implementing and operating systems, basic technical knowledge, professional competencies, personal attitudes towards the engineering profession, as well as interpersonal skills, such as team work and communication, are required.

3.3. The twelve standards
The CDIO program is furthermore described at a principal level in form of twelve standards. These standards are a help for an institution in the implementation of the CDIO concept, as well as they are supporting the continuous improvement of the education. CDIO does not work with formal certification processes; instead, it is up to each institution to self-certify themselves according to the standard. The standards are found in table 2 below.

| Feature               | Standard                                      |
|-----------------------|-----------------------------------------------|
| CDIO philosophy       | 1. CDIO as a context                          |
| Curriculum            | 2. CDIO syllabus outcomes                     |
|                       | 3. Integrated curriculum                      |
|                       | 4. Introduction to engineering                |
| Workspace             | 5. Design-build experiences                   |
|                       | 6. CDIO workspaces                            |
| Teaching and learning | 7. Integrated learning experiences            |
|                       | 8. Active learning                            |
| Faculty competence    | 9. Enhancement of faculty CDIO skills         |
|                       | 10. Enhancement of faculty teaching skills    |
| Assessment            | 11. CDIO skills assessment                    |
|                       | 12. CDIO program evaluation                   |

The first standard addresses the **philosophy and context of CDIO**. CDIO adapts a life cycle perspective on systems and engineering, expressed in the abbreviation itself: CDIO. This goal must be expressed in a clear and consistent way in a mission statement or the similar. Moreover, it is important that teachers, administrators and students knows about this goal. Therefore, having it expressed in formal documents is not enough; it should be reflected in the daily activities of education. The next three standards are connected to **curriculum development**. Standard two directly address the education outcomes in form of the CDIO syllabus. These outcomes, the third standard express, should be trained in an integrated mode during the full education. To succeed with this, a specific matrix has been developed for assuring the integration, training and progress of trained skills at program level as well as on course level. The fourth standard highlights the importance of the first **introductory course**. This course should be a thorough introduction to the engineering profession, where the
students can create a first broad picture of their future work. Practical understanding is important, preferably given by active engineers from industry. Small project based problem solving activities to prepare for further more in-depth studies are also appropriate activities in the introductory course. Standards five and six address the learning environment. Hand-on experiences, project work and student-centered learning demand appropriate activities and work places. Course assignments should be designed to activate the students, and at least two design-construct activities (one for instance in the first year and one in the last year) should be included in the curriculum, and suitable laboratories, equipment and study facilities (for instance small rooms available for student group meetings) should be provided. The next two standards highlight the need of new methods for teaching and learning. Traditional teaching must be supplemented with activities which train problem definition and solving, information searching and analytical skills, written and oral communication, team work, reflection and argumentation, and of course required engineering knowledge. Examples of such activities are project work, laboratories, presentations, reflections and discussions. CDIO recognizes that a new way of working require support for faculty development (standards nine and ten). Teachers must for instance have understanding of CDIO and its goals, as well as help in developing the teaching towards a student-centered approach. The last two standards address assessment and evaluation. We need to continuously evaluate and improve our work, and therefore both the individual students’ skills training and the full program must be assessed and evaluated. Individual skills are assessed formally in the different courses that comprise the education, and in the independent work conducted at the end of the education, while evaluation is made on course and program level by students and faculty and is used as input for improvements.

4. Programs and education within Total Quality Maintenance

In this section education at the department for Technologies of Maintenance and Production Management at Linnaeus University in Sweden is described. We first give a brief historical description of the development of the subject Total Quality Maintenance, and educational programs connected to the subject. Thereafter the general teaching approach is introduced.

4.1. Education within Total Quality Maintenance

Education within terotechnology has been carried out at Växjö University, now Linnaeus University, since the 1990s in form of single subject courses and, in the beginning, one four-year master program entitled Industrial Terotechnology. The subject is classified as belonging to the technological/engineering discipline at the school of engineering. The education is unique in Sweden as it is the only one entirely focusing on terotechnology. Terotechnology is a multi-disciplinary subject with its roots in industrial asset management. As such, terotechnology is defined as the economic management of assets. It is the combination of management, financial, engineering, and other practices applied to physical assets such as plant, machinery, equipment, buildings and structures in pursuit of economic life cycle costs [6]. In later years the concept was broadened to include all kind of assets within an enterprise, such as human workforce and information, and the educational subject changed name to Total Quality Maintenance. At the same time, a new four-year master program was launched: Human resources and Industrial Management.

In the middle of the 2000s, three programs were given within Total Quality Maintenance: two four-year master programs and one broadening master of one year, where students from other disciplines with a Bachelor degree could achieve a broadened master in either Production management, Quality management or Maintenance management. At that time, the educational system was changed in Sweden according to the Bologna system. The four-year programs were revamped into three-year bachelor programs and the broadening master year became a one-year master program with clear focus in the terotechnology concept. The one-year masters’ program was extended into a two-year master in 2010. The same year, one of the bachelor programs was revamped into a combined engineering and bachelor program with focus on maintenance management.
4.2. Program setup and general teaching methods

The three programs have different setups depending on the purpose of the program, but there are some general characteristics. Firstly, all programs aim at creating a holistic understanding of an enterprise or a production system, with specific focus on the production, quality and maintenance areas. This is achieved in the three-year programs by first applying an overall understanding of the enterprise with its processes in year one, thereafter different processes and systems are studied in detail during year two and three, and in the end of the third year a holistic perspective is again applied, but now in a more detailed level in case studies and degree projects. The two-year master is set up almost the same, but with the difference that the maintenance and process assurance is in focus in the first year. Secondly, all programs combine theoretical knowledge with training of generic skills. Therefore the teaching method for all courses within the major subject is the same.

The teaching method applied within Total quality Maintenance is called Project-based learning, a special form of problem-based learning [7]. The method was applied already in the 1990s, and has continuously been developed to fit new circumstances, such as student group size and mix, course contents and cooperation with industry. The main setup for a course within the subject is the following:

1) Course introduction
   The aim and objectives with the course is described. A thorough description of teaching methods, expected learning outcomes, grading criteria, content and schedule and other important information regarding the course is given. The information is thereafter available online for students to find. All activities that forms the examination are described either fully here or later on in the course, depending on the type of assignment and if the students needs to have some specific knowledge to understand the assignment. All assignments and templates to be used are published online for the student to reach whenever and wherever. In this step the understanding of the general course setup and goals are in focus.

2) Theoretical introduction
   Main concepts and theory are introduced in lectures. In parallel with the theoretical introduction the students are mainly reading the mandatory course literature and might be working with simpler assignments or laboratory exercises. In this step the basic theories and knowledge is in focus.

3) Students’ active learning
   Theory is deepened and different perspectives are added. The teaching consists of lectures, exercises, laboratory sessions, study visits, guest lectures and presentation seminars. The student is actively understanding the theory by studying literature, both mandatory books and additional reading, searching information within the subject, doing homework and group based exercises and by laboratory work or other practical activities. The theoretical understanding is supported by a more practical understanding by study visits, guest lectures and laboratories. The focus is to understand the theory.

4) Students’ active use of knowledge
   Finally the students will use the knowledge gained by discussing, analyzing, explaining and comparing theory and practice. In most courses this is made in project form at a case company. The project is carried out by a group of students, who document the findings in a report. The findings from the projects are presented and discussed orally within the class. There are many applications of this standard work method, but the main objectives are the same: the students should be able to apply and use the theories to reach a deepened understanding of the subject.

5. Educational practices in the engineering program according to the twelve CDIO standards

In the previous section the general education setup was addressed. In this section we will look closer at one program, the three-year undergraduate engineering program in Industrial engineering with specialization in Maintenance Management. The development, setup and content of the program are described with the basis in the twelve CDIO standards. For each standard, we bring up examples of how it affects the educational program. We also outline the future improvement potentials.
5.1. Program philosophy

In an information folder for engineering education published by the School of Engineering the program directors give their view on what characterizes the education program (translated from Swedish):

“L. and A. believe that what is special with the education is the way of learning during the studies. The recipe is to give main parts of the education in project form, to offer varying assessment forms, small student groups, which create good connections between teachers and students and closeness to the current research, and real case studies on companies in almost all courses.

– This makes the students capable to take care of their own development at the future work place already during the studies, A. says”

The focus on CDIO capabilities is thus found already when trying to recruit new students. It is notable that the actual term CDIO is not used. Instead, the main idea behind CDIO is addressed. On the University web site interviews with program students are published as another means to inform and recruit prospective students. In these interviews the company contacts, the holistic approach to company activities and training in English during the education were some of the things the students pointed out as positive aspects. In the formal program syllabus the innovative perspective is not highlighted enough though. The focus is on what rather than how it is taught. The close cooperation with industry and the combination of theoretical and practical understanding is mentioned though:

“The program is completed in close contact with trade and industry. Every course within the subject erotechnology contains practical cases where theory and practice is woven together and carried out at an industrial company. Guest lecturers from industry and field trips to relevant companies also occur during the program.”

The faculty is well aware of the teaching methods and the benefits they bring. The teaching concept with the basis in project-based learning has a long history and has during the years been further developed. It has also been documented internally in form of templates, guidelines and plans. Some of these will be described further on.

The ideas of CDIO is currently utilized in practice, but as an important improvement step the approach should be better communicated to different interest parts. Firstly, the information provided in folders, catalogues and the web should clearly state the mission and goals for the education with respect to CDIO. Moreover, the program syllabus should include a description of the education setup.

5.2. Curriculum development

Working with the CDIO syllabus is often not something that is made from scratch. So in our case; we had previously defined and articulated competencies we found important for a future engineer. We had also developed plans and strategies for reaching these, but these efforts were scattered in several different documents, both official and internal. The program syllabus for instance clearly defined the knowledge contents of the education corresponding to the competencies expressed in the first category in the CDIO syllabus. Moreover, the generic competencies, corresponding to the second and third category in the CDIO syllabus had been mapped with respect to objectives, activities and progression for the education within the subject, but not for specific programs. In addition, plans for information search, strategy and assessment had been developed in cooperation with the library personnel for each program. The life cycle perspective of CDIO, which is addressed in the forth category in the CDIO syllabus, was recognized and expressed in a slightly different way for the subject of Total quality Maintenance, see section 4.2.

As an important first activity when adapting current educational policies to CDIO, the different documents and plans were gathered and integrated into one common matrix; see appendix A. In this
matrix, the program content has been mapped against the CDIO syllabus on a high level. The progression of skill training is expressed in three levels: the skill is introduced but not assessed (I), the skill is taught and assessed (T), and the skill is utilized by the student (U). The next step will be to map the contents on a more detailed level, and to certify that the mapping is correct with respect to course content and skill progression. Thereafter the course syllables will be rewritten, especially to include learning outcomes that are focused on personal and interpersonal skills. In focus when updating the syllables are the skills marked with a “T” in the matrix, because these are actively taught and assessed during the course, and therefore these should be expressed clearly as a part of the expected learning outcomes.

A thorough introduction to the engineering profession as well as the CDIO teaching program is made in the very first course entitled “Introduction to industrial operations”. In this course theoretical studies are mixed with practical understanding of the subject area. The practical understanding is gained by study visits and laboratories in enterprise resource planning (ERP) systems. The course consists of lectures, study visits, laboratories and exercises covering production and production logistics, quality and quality management, maintenance, reliability and life cycle costing, business economy and information systems. Thus, a clear holistic approach is applied. All these parts are thereafter studied in more depth during several courses, and in the end of the education the holistic approach is once more applied but now in more depth. The introductory course also includes a small team based project work. The actual project task is given in several smaller assignments, which in total forms a whole. In this way, different learning skills and competencies could be introduced bit by bit, and the probability of a total failure for an individual student on the very first university course will be reduced.

5.3. Design-build experiences and workplaces

Facilities that allow hands-on and student-centered learning are of course a prerequisite for creating a good learning environment. The Linnaeus University is a modern facility with good possibilities to create active learning environments. The students have access to the wireless internet connection and can therefore easily work team based either directly at site or utilize modern communication for coordinating the work. Several group rooms and corners with chairs and tables are available for students to book and use. The library resources are also excellent, and the lecture rooms all have computers and projectors installed. The computer rooms are well equipped with software needed and machine laboratories as well as chemical laboratories are available, but not being a technical university, the laboratories could be improved. This affects the industrial engineering students to less extent than e.g. the mechanical students though.

The industrial engineering contains less natural design-build situations than for instance mechanical engineering; the systems are simply put less physical. We try to create hands-on and real-life resembling experiences to compensate this. Examples of such activities are laboratories in real ERP systems and other software, case studies where real industrial scenarios are studied or real industrial problems are solved. The course “Asset Health Management” includes laboratories in vibration measurement as failure assessment, where students get real-life experiences in measurement method and technology, see figure 2. In the “Cost analysis” an asset investment decision is made based on real situations in case companies. The students are thus utilizing life cycle costing and multi criteria decision making knowledge when studying a real investment situation in a case company. The “Case study” and “Degree project” are both courses that are conducted in companies and where a real industrial problem is solved. In the degree project the students formulate their own problem, either by themselves, or in cooperation with industry. The students have to independently identify a suitable industrial partner and make contact with it. The degree project is often in form of a development or improvement work, where the students design a solution and thereafter implement it, which require the students to stay at the company for a longer time period.
5.4. New methods of teaching and learning

The general education setup of the main subject as described in 4.2 promotes student active learning and adequate training in the CDIO skills. Therefore this part of the CDIO initiative was already met when implementing the program. Doing something today does not mean we cannot do it better, so the CDIO program will be used for further improving current methods utilized for teaching and learning.

A variety of student teaching and learning methods are used. Lectures and student assignments are commonly utilized for introducing a new subject and for students to work on the topic to get a basic understanding. Exercises, laboratories and study visits are utilized for deepening the understanding and to illustrate or apply the theories in practice. These activities are often formally reported in written form and discussed during seminars. Independent work or group based projects are usually applied in the end of a course where the students can prove their abilities to define problems within the specific topic, apply a suitable method for solving it, collect relevant theoretical and empirical information to analyze, and then report, discuss and critically reflect on the results. In the end of the course oral presentations, discussions, oppositions, argumentations or reflections are often combined with the written reports.

The students are activated throughout the course by mandatory assignments and activities. These assignments are utilized both for assessment and feedback. One example could be the training in a certain method such as failure mode effect and criticality analysis (FMECA). The students learn the method by doing assignments with given data. The assignment is corrected by the teacher and feedback is given. Thereafter the students utilize their knowledge in a project where real company data is gathered for creating a FMECA. An example of how a course could set up is found further on in 5.6.

5.5. Faculty development

An education program could not be realized without support from the faculty, and especially the active teaching personnel. Within terotechnology all personnel are active in teaching. The basic policy could be expressed as: everyone working at the department should have equal possibilities to be active in education as well as in research. This means that professors mainly doing research also are active in teaching and educational development. Similarly, the non-researching personnel are provided research experiences and possibility to qualify both in teaching and research. Education and educational development is thus something that affects everyone. Another basis for successful implementation is
cooperative work. Each subject area forms loosely tight teams of teachers, which plans, develops and executes teaching. Special meetings are also arranged for all teachers involved in the education, where teaching is discussed. During these meetings assessment methods, student activities or experiences are shared. Course specific material, everything from planning and scheduling to lecture slides, are kept in a common data repository. This transparency in how and what we teach creates good possibilities to learn from each other, to switch between courses as a means to develop as teacher, and most important, is the prerequisite for applying a common educational program such as in this case CDIO.

5.6. Skills assessment
The assessment methods should match the expected learning outcomes. A written exam could for instance not assess the team work skills or the ability to express and discuss something in oral form. Therefore we apply several different assessment methods that best could prove the skills of the student. In Table 3 one example of course specific learning outcomes, assessment methods and examples of CDIO outcomes for the course “Integrated business solutions” is found. Note: Business solutions are integrated holistic information systems that support information retrieval, processing and sharing in an organization. They are often synonymously called ERP systems, even if ERP systems in general provide less functionality coverage than a business solution.

| Learning outcome according to course syllabus | Assessment method | CDIO outcomes (examples of) |
|---------------------------------------------|------------------|-----------------------------|
| Account for the concept business system; its structure, field of application and its connection to the main processes within an enterprise | Laboratory report (Pairwise) Laboratory seminar (Individual) | 1.2 Core engineering fundamental knowledge 2.2 Experimentation and knowledge discovery |
| Understand the use of a business system depending on user role | Laboratory report (Pairwise) Laboratory seminar (Individual) Reflections (Individual) | 1.3 Advanced engineering fundamental knowledge 4.2 Enterprise and business context |
| Understand possibilities and limitations within the use of business system | Reflections (Individual) Paper (Individual) Discussion seminar (Individual) | 1.3 Advanced engineering fundamental knowledge 2.4 Personal skills and attributes 3.2 Communications |
| Analyze requirements and based upon these choose the most appropriate business system | Exercise (Group based) | 1.3 Advanced engineering fundamental knowledge 2.1 Engineering reasoning and problem solving 2.2 Experimentation and knowledge discovery 2.5 Professional skills and attitudes 3.1 Teamwork 4.3 Conceiving and engineering systems |
| Assess the benefits of business systems | Paper (Individual) Discussion seminar (Individual) | 1.3 Advanced engineering fundamental knowledge 2.5 Professional skills and attitudes |
| Discuss business systems with respect to business processes from an integration perspective | Discussion seminar (Individual) | 1.3 Advanced engineering fundamental knowledge 2.3 System thinking |
In all six activities forms the course assessment: a laboratory report, written reflections, a paper or essay, two seminars and one exercise. Three laboratories are held where the students learn different functionalities and processes of a real ERP system. The results from the laboratories are summarized in a laboratory report, which is discussed at a teacher-led seminar. The focus of this seminar is the concept and use of business solutions. A set of study visits and guest lectures are given, and the written reflections are connected to these. For each visit or guest lecture, the student reflects on the perspective given (developer, user, consultants, etc.), the main message of the speech, and what main problems and possibilities the speaker identifies. The problems and possibilities should be identified with respect to type (economic, organizational, technical etc.). Each student also writes a larger paper on business solutions. In this paper the student has to bring forward possibilities and threats, strengths and weaknesses, and discuss the benefits of business solutions with respect to a certain perspective applied in the paper. The perspective could for instance be implementation or information quality. In the end of the course a discussion is held with basis in the individual papers. The discussion is in half class and is student-led, and as preparation each student reads the other students’ work (in all about five to seven). The students have been assigned one specific paper to read more thoroughly, and the student is responsible for leading the discussion that is held for this specific paper. In addition, the students perform a five hour long exercise in IT procurement. This is a role play based exercise where the students acts as a project group responsible for defining requirements, find suitable candidate ERP systems and evaluate the alternatives with respect to the requirements specified.

As seen in the rightmost column in table 3 the course trains several of the skills in the CDIO syllabus. Basic knowledge within industrial engineering, as well as deepened with respect to information systems, is provided in the course. Moreover, the IT procurement exercise trains the problem solving capabilities, team working skills and professional attitudes towards IT procurement due to the role playing setup and the open ended task, where no absolute correct or incorrect answer exists. The laboratories provide hands-on experiences and train the experimentation and knowledge discovery skills. The seminars train oral communication skills and the paper, reflections and reports trains writing. The paper is an independent work where the students train several of the CDIO skills, but mainly the personal skills and attributes, such as time management, creative thinking and risk taking. The reflections also trains personal skills such as critical thinking, because the student has to assess the rather subjective information given from industry representatives and make it fit to the general course subject. In addition to the mentioned skills, the systems thinking is provided in this course, where the subject of integrated business solutions is treated from technical, economic, organizational as well as the individual human’s perspective.

5.7. Education assessment and evaluation

Courses as well as the programs are continuously evaluated. A written anonymous evaluation is made after each course, and in the end of the study program. Courses and the programs are also evaluated more informally during program meetings. The student organization does additional evaluations. All these evaluations are documented and a small development plan is written by he teacher for each course based on the evaluation. This feedback on the evaluation is documented together with the evaluation summary and is communicated back to the current students. Evaluation results and changes made in the course are thereafter communicated to the new students during the course introduction the next time the course is given. Program evaluations are similarly used as input for improvement activities. In addition, the program council which is formed by industry representatives, students and program directors, discuss quality, content and future development of the programs. This in order to assure that the content fits the industry needs. Long term evaluation is made on alumni both formally and informally. Formal alumni surveys are conducted regularly at the school. Informally, we keep contact with previous students by mail, meetings and the subject Facebook group. Once a year we contact the students who left us the past two years and ask them what they work with and what their apprehension of the studies were.
The CDIO program gives us a good basis in what questions to ask when conducting different evaluation. Already today we have standardized question and questionnaires for course, program and alumni evaluations, but in the future these would be updated with respect to the CDIO syllabus to ensure that all aspects of the syllabus are covered in evaluations.

6. Results and concluding remarks
Applying CDIO to the Industrial Engineering program is still an ongoing project. We have so far started the huge work with ensuring the training and the progression of the skills according to the CDIO syllabus. The next step will be to reformulate course syllables to better reflect the actual learning content and learning outcomes. Another important future activity is to develop the understanding of CDIO within the faculty. The CDIO initiative will be implemented in several of the educational programs at the School of Engineering, and the project with the Industrial Engineering program is one way to gain more experiences and find suitable means to implement the CDIO concept at the school, i.e. to find our own way of approaching the CDIO philosophy. Already now we can report on benefits with applying an innovative educational program, such as:

- Well defined introductions for the new engineering students and a clear progression of engineering skills training throughout the programs
- Better connection between teaching and assessment, utilizing a variety of assessment methods
- Better coordination and utilization of industry and other interest parts throughout the program
- Active and motivated students by applying active and student centered learning methods
- Low level of program dropout

In the future we expect additional benefits, e.g. better cross-department and cross-faculty cooperation, development of the internal knowledge in CDIO for creating out own way to approach the CDIO philosophy, improved program and course syllables and better utilization of the resources, for instance in form of teachers, laboratories and IT support.

Applying an innovative educational program such as CDIO might be seen as a hard and tiresome process, but our experience is that it is worth the initial investment. The benefits are, to our experience, several. Firstly, it sets education and educational development on the faculty agenda. By documenting objectives, strategies and teaching methods these could be communicated to a broader audience, for instance to industry partners or students, and it promotes cooperation between faculty members. The documentation allows for more deep and targeted evaluation of activities, which is the basis for development and improvement work. The effects in summary are higher quality in education and a better fit of content with industry demands, which will lead to students with high employability.

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Appendix A

## CDIO-syllabus

| Year 1: | Year 2: | Year 3: |
|---|---|---|
| Basic mathematics | Calculus | Vector geometry |
| Mechanics | Statistics | Mathematical statistics |
| Industrial operations | Engineering economy | Computer Aided Engineering |
| Development | Quality technology | Management in manufacturing |
| Reliability engineering | Working life in late modernity | Methods for process improvement |
| Asset health management | Simulation | Cost analysis |
| Reliability engineering | Management | Reliability engineering |
| Integrated business systems | Case study | Degree thesis |

### 1. Technical knowledge and reasoning

1.1 Knowledge of underlying sciences | 1.2 Core engineering fundamental knowledge | 1.3 Advanced engineering fundamental knowledge |

### 2. Personal and professional skills and attributes

2.1 Engineering reasoning and problem solving | 2.2 Experimentation and knowledge discovery | 2.3 System thinking |

### 3. Interpersonal skills: teamwork and communication

3.1 Teamwork | 3.2 Communications | 3.3 Communication in foreign languages |

### 4. Conceiving, designing, implementing and operating systems in the enterprise and societal context

4.1 External and societal context | 4.2 Enterprise and business context | 4.3 Conceiving and engineering systems |

### Notes

I: The skill is introduced but not assessed
T: The skill is actively taught and assessed
U: The skill is utilised, (assuming the student to have the skill)