USING STUDENTS' REFLECTIONS ON PROGRAM GOALS AFTER MASTER'S THESIS AS A TOOL FOR PROGRAM EVALUATION

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ABSTRACT

This paper presents initial experiences and results from the content analyses of reflection documents made by students after finishing their Master's theses. The reflection document is a compulsory part of the examination of the Master's thesis since spring semester 2011.The main objectives of the reflection document has been to give feedback to examiners and program boards about how the learning outcomes of the program are fulfilled and how the student's individual skills have developed during the thesis work. At the Institute of Technology at Linköping University all engineering programs use the CDIO-syllabus, slightly modified, to express goals and learning outcomes. Since there is an upcoming national evaluation of engineering education in Sweden this study is an initiative to test if the reflection documents can be used as a complement in the evaluation process to provide evidence of fulfillment of the national program learning outcomes. This pilot study includes a subset of all the submitted reflection documents. The result from this study indicates that the method used can provide evidence of the students' perceptions of the program and fulfilment of the goals. The findings show that the students find most of the learning outcomes fulfilled although some areas must be clarified and improved.

KEYWORDS

Learning outcomes, evaluation, reflection document, content analysis.

INTRODUCTION AND BACKGROUND

Previous studies [1, 2, 3, 4, 5, 6] have demonstrated that the CDIO-syllabus is a very useful tool to organize and develop study programs. ITU matrices have been used by program management on both course level and program level as tools to verify learning outcomes and program goals. Also the importance and impact of the project courses have been shown in these studies. This study continues to analyze the impact of CDIO concept in the most important individual course; the Master's thesis [7].

The project model, LIPS-model [8], at Linköping University has been a backbone in several project courses. In the Applied Physics and Electrical Engineering program and the program Engineering Biology the model is used in a sequence of project courses, introductory course during year one, design—build courses in year three and four. As a part of the LIPS-model the student writes a reflection document at the end of the course.

At the end of the program, the students write the final Master's thesis, often done in cooperation with industry. As a part of the examination of the Master's thesis the students have to write a reflection document in which they reflect on:

– How their individual skills were developed during the Master´s project.
– How well the process of doing a Master´s thesis went.
– How the student's own contribution affected the implementation and outcome.

– How well the program succeeded in its task to ensure that learning outcomes are met.

The two latter ones are used as feedback to both the examiner of the Master´s thesis as well as to the program management.

The Institute of Technology at Linköping University has delegated to Program Boards to plan, follow up and evaluate programs and to ensure continuous quality improvement within their area of responsibility. The Program Boards consist of faculty members, representatives from industries and student representatives and are responsible for their different subject areas. The different subject areas are 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). The Program Boards decide on Syllabi, Curricula and Course Plans for the programs. Special development groups, appointed by the Board, revise the syllabus, curriculum and course plans each year in cooperation with the departments. The Dean meets the chairmen and the director of studies of the Program Boards every week to lead and coordinate the work. These meetings are the platform for discussions around program development. One of the main issues for the group, LGU, is in 2012 the upcoming national quality evaluation.

The National Agency of Higher Education has been commissioned by government to review all engineering programs in Sweden [9]. In contrast to previous evaluations [10] that focused on preconditions and processes for quality, the upcoming evaluation is directed on results; that degree objectives are met.

The National Agency has chosen an evaluation method where strong emphasis is put on students' performance in their Master´s theses, the argument being that the Master´s thesis best reflects the result of the program [11]. The outcome of these studies, combined with the self-evaluation made by the program management, will form the basis for the assessment.

The Self-evaluation should also serve as an important instrument in the university's own work to ensure quality of education. The university should in this document analyze and evaluate the results in relation to the goals and ensure that the students reach the learning outcomes for the degree, Appendix 1. These learning outcomes were not originally written to be evaluable.

In the context of the Bologna reform in Europe and the degree reform in Sweden in 2007, the Government decided to add a requirement of an independent work (thesis) for almost all degrees. The Government also emphasized the thesis to have a central role to confirm that the students have achieved the requirements for the degree.

It is the overall quality of the independent work (thesis) for a certain degree that is the basis of the judgment, not in every single one. Note that the independent work (thesis) normally is not going to be the only basis for the review.

For each type of degree a random sample of theses is selected, up to the number of twenty-four. The sample will be de-identified regarding author and university. If there are less than five diplomas issued within the review period this specific degree is excluded from the review.

CDIO IMPLEMENTATION

Linköping University (LiU) is one of four the original collaborators in the CDIO initiative. Initially, the program Applied Physics and Electrical Engineering participated in the initiative, but the ideas were spread within LiU and were adopted by other programs. The process to develop and redesign the Applied Physics and Electrical Engineering program is described in [12] and [13]. During the Bologna reform 2006 the Faculty Board took a decision that all programs at Linköping Institute of Technology at Linköping University should use CDIO syllabus as a base when goals and learning outcomes for programs and courses were formulated. The LGU management group took an important role to manage this. [6]

In preparation for the coming evaluation the program boards have started to write their self-evaluations based on the Higher Education Ordinance´s learning outcomes for the current degree, Appendix 1, but for each goal there is a transformation using CDIO-syllabus Linköping style (LiU style), Appendix 2, since the program goals and learning outcomes are organized this way in Linköping.

Table 1
Scheme of the transformation from Higher Education Ordinance to LiU CDIO-syllabus

Learning outcomes in Higher Education Ordinance. (See Appendix 1)	Learning outcomes in CDIO-syllabus (See Appendix 2)
1	1.1-1.3
2	1.1-1.3
3	2.1-2.4
4	2.1-2.5, 4.3-4.5
5	1.3, 2.1, 2.4
6	2.1-2.4
7	4.1-4.6
8	3.1
9	3.2-3.3
10	1.1-1.3, 2.5, 4.6
11	1.2, 1.3, 2.5, 4.1, 4.6
12	2.4-2.5

At Linköping University the learning outcomes for the thesis also follows the CDIO-syllabus regarding the different main parts.

Below is an excerpt from the course plan for the thesis:

Aim:
Knowledge of underlying sciences
The student is expected to:

- systematically integrate knowledge aquired during the studies
- demonstrate knowledge and understanding in the main field of study, including both broad knowledge in the field and substantially deeper knowledge. Demonstrate deeper methodological knowledge in the main field of study.
- be able to assimilate the contents of the relevant literature and relate their work to this

Personal and professional skills
The student is expected to:

- plan, implement and document an independent degree project
- formulate issues, plan and carry out advanced tasks within specified time limits
- find and evaluate relevant literature

Teamwork and Communication
The student is expected to:

- demonstrate ability to clearly present and discuss conclusions on the degree project in writing and orally
- critically examine and oppose on another student´s degree project

CDIO science
The student is expected to:

- be able to create, analyze and/or assess scientific issues in theories and methods
- Be able to make judgments with regard to relevant ethical and societal conditions such as economically, socially and ecologically sustainable development.

Figure 1. Excerpt from Master's thesis course plan

The examination of the project is divided into five parts: written report, oral presentation with opposition, reflection document, opposition on a fellow student and attendance to at least three oral presentations of theses. As a part of the written report the student must provide a project plan for the thesis work and a half-time evaluation of the plan.

Since it is not known in advance how the coming evaluation actually will be carried out, different kinds of preparations have been national made. One is the collaboration between Umeå University and Linköping University, where peer review groups were appointed to evaluate theses from the both universities. The main finding is that it is possible to evaluate quality this way. This work stressed the importance of an additional document connected to the thesis that also describes the working process [11].

REFLECTION DOCUMENT AS AN EVALUATION TOOL

The connection between the Master's thesis and the reflection document and how the reflection should be carried out and reported is described in an attachment to the course plan for the thesis [14]. The following instructions are given to both examiners and students.

"Since the thesis work is an independent work performed at the end of the program, the students' gained knowledge and skills are applied and used. The thesis work also means a deepening within the field of education. The objectives of the Master's thesis are set out in the course plan" [14].

In addition to the written report, a reflective discussion paper where the thesis work should be put in relation to the knowledge and skills acquired during the education. The report is provided to the examiner.

The objectives of the reflection document are:

- to reflect on how the individual skills have developed during the thesis work.
- to give the examiner and the program board feedback on how well the process of doing a thesis has worked and how the student's own contribution has affected the implementation and outcome.
- to provide feedback to the program board for how well the educational program has succeeded in its task to ensure that the objectives of the program are met.

The following topics are to be included in the reflection document:

Reflection on how the Master's thesis relates to the goals of the program

- How does the actual thesis relate to the educational goals of the program?

Reflection on the student's own work

- Planning
  Was the planning a good support for the implementation? Was enough time put on planning? Were the preconditions satisfactory for the work? The thesis work should correspond to a particular workload, (1.5 credits = one week of full-time job), how well does this correspond to the thesis work?
- Implementation and report writing
  Was the time available for writing satisfactory? What was problematic and why? What went better than expected and why?
- In cases where the thesis work was performed together with another student, describe how the division of the work has been done. Describe if the cooperation has been positive or negative, and in what way. Reflect on the amount of independence in the Master's thesis.
- Was the preparation adequate to write a degree work report? Were the language skills sufficient (English, other language)? Was the Master's thesis satisfactory carried out?

Reflection on the subject content, knowledge, skills and attitudes that were most useful for the completion of the Master's thesis

- What areas and course modules of the education have been most useful for the thesis work, and what new knowledge and skills have been necessary to complement with to carry out the work? Is this a sufficient preparation for a future career, the Master's thesis and program over all?

The scope of the reflection document is 2–4 pages and it is handed in to the examiner who also passes it on to the program board.

To actually be able to use all information from the reflection document in the evaluation process a template for a summative content analysis [15] was developed. Since The National Agency of Higher Education will use the goals from the Degree Ordinance the twelve different goals were initially chosen as themes for the content analysis. Soon it was clear that the different themes were overlapping and the solution was to cluster the goals which were close to each other.

Finally there were six different themes built from originally twelve goals.

1. Knowledge and understanding of the subjects based on goal number 1 and 2
2. Skills and abilities regarding scientifically methods based on goal number 3,4 and 6
3. Skills and abilities regarding team and project work based on goal number 5 and 8
4. Skills and abilities regarding communication based on goal number 9
5. Judgment and approach regarding societies' needs based on goal number 7,10 and 11
6. Understanding of the need of Lifelong learning based on goal number 12

Figure 2. Six themes for the content analysis based on clusters

Totally 56 reflection documents from four different Master's in Engineering programs have been reviewed and analyzed. They have been selected in no particular order from submitted documents.

The selected programs and the number of analyzed documents were:

- Applied Physics and Electrical Engineering (Y), 32 documents.
- Computer Science and Engineering (D), 13 documents.
- Electronics Design Engineering (ED), 5 documents.
- Media Technology (MT), 6 documents.

The contents within the reflection documents are compiled and commented according to the six themes mentioned earlier. During the review students' comments on learning outcomes have been chosen. Each student's comments on a specific learning outcome were counted once.

Initially, one noticed that the reflection documents differ a lot from each other even though there is a template to follow.

Some of the students use the program goals one by one to make comments. Other students reflect over the Master´s thesis work regarding to the program goals in continuous text and made comments on what seems important or obvious to themselves.

The following is the summary of the outcomes for each theme and some citations from the reflection documents.

Theme 1: Knowledge and understanding of the subject, based on goals number 1 and 2

1. Demonstrate knowledge of the scientific basis and proven experience of their chosen area of engineering, together with insight into current research and development work (CDIO-Syllabus 1.1–1.3)

2. Demonstrate both broad knowledge in their chosen area of engineering, including knowledge of mathematics and natural sciences, and substantially deeper knowledge in certain parts of the field. (CDIO-Syllabus 1.1–1.3)

Table 2.
Number of reflection documents with one or several statements on theme 1

Learning outcomes	Applied Physics and Electrical Engineering (Y)	Computer Science and Engineering (D)	Electronics Design Engineering (ED)	Media Technology (MT)

Knowledge of scientific basis	20	8	5	5
Insight into current research (excellence)	21	3	4	5

Most of the students make comments on what they have learnt during the program. They mention basic knowledge and /or profile courses. Almost all students mention courses that were useful for them during the thesis work.

Some quotes illustrate this.

Y: "During the thesis work both knowledge of scientific basis and depth has been demonstrated. Knowledge from various fields have been used to successfully achieve the objectives of the thesis"
D: "The earlier studied courses have given knowledge to understand the underlying theory for the methods and technology used to carry out the thesis work."
MT: "I have a stable base in mathematics, natural sciences and engineering"
ED: "The broad basis of knowledge and the holistic perspective I have gained from my program have given methods to analyze and implement electrical engineering solutions."

Figure 3. Quotes from students, statements on theme1

Theme 2: Skills and abilities regarding scientific methods, based on goals number 3, 4 and 6

3. Demonstrate an ability, from a holistic perspective, to critically, independently and creatively identify, formulate and deal with complex issues, and to participate in research and development work so as to contribute to the development of knowledge; (CDIO-Syllabus 2.1–2.4)

4. Demonstrate an ability to create, analyze and critically evaluate different technical solutions
(CDIO-Syllabus 2.1, 2.2, 2.3, 2.4, 2.5, 4.3, 4.4, 4.5)

6. Demonstrate an ability to integrate knowledge critically and systematically and to model, simulate, predict and evaluate events even on the basis of limited information; (CDIO-Syllabus 2.1–2.4)

Table 3.
Number of reflection documents with one or several statements on theme 2

Learning outcomes	Applied Physics and Electrical Engineering (Y)	Computer Science and Engineering (D)	Electronics Design Engineering (ED)	Media Technology (MT)
Complex issues	8	4	1	2
Problem solving	21	7	4	4
Contribute to develop knowledge, processes, products	13	2	3	1
Create, analyze, evaluate	21	8	4	6

Most of the theses are carried out in industry and most of the projects are advanced tasks which involve creating new products, processes and/or problem solving. In the reflection document many students commented on this, but not all.

The following quotes illustrate this.

Y: "System thinking has been used as sub-system through models that have been integrated to bigger systems. Models have been created and used to create test variables in a diagnostic system. The function has been validated and evaluated."

Y: "My ability to structure, formulate and solve problems of this complexity comes from the training within the Y-program. Most useful is the training within the CDIO-project."

D: "The knowledge of how to create and develop a design of a system has been most useful during the thesis work. This has especially been trained within the project courses."

ED: "The thesis work was a wonderful opportunity to apply knowledge both in mathematics and engineering. One had the opportunity to gain additional knowledge, look for more information, value the information and finally solve the problem."

Figure 4. Quotes from students, statements on theme 2

Theme 3: Skills and abilities regarding team and project work, based on goal number 5 and 8

5. Demonstrate an ability to plan and, using appropriate methods, carry out advanced tasks within specified parameters; (CDIO-Syllabus 1.3, 2.1, 2.4)

8. Demonstrate an ability to engage in teamwork and cooperation in groups of varying composition;
(CDIO-Syllabus 3.1)

Table 4.
Number of reflection documents with one or several statements on theme 3

Learning outcomes	Applied Physics and Electrical Engineering (Y)	Computer Science and Engineering (D)	Electronics Design Engineering (ED)	Media Technology (MT)
Plan and use appropriate methods Project	19	6	4	5
Teamwork, cooperation in groups	11	2	1	2

As mentioned earlier, the students during the first weeks of the thesis work have to make a project plan of how the work is intended to be carried out. Halfway into the thesis project the student presents a half-time report to the examiner how the work is progressing relative to the initial project plan which is then updated. All students could actually claim in the reflection document that they have learnt to do a project plan. Not all do.

The thesis work usually is carried out alone or in cooperation with another student. More than two students are not allowed to work together.

When the students reflect on teamwork and cooperation in groups, they either worked in groups at the company, or they refer to project courses within the program. Y-students refer to the CDIO-projects, D-students to the Software Engineering project, MT students to Modeling project and ED-students to Project Mobile Autonomous Robots and Project Management.

Quotes about teamwork and cooperation:

Y:	"Earlier during the CDIO-project I have been a part of a team working to solve a problem. Everyone in the team had something they knew better than the others in the group and together we managed to build a product that was very competitive."
MT:	"To work with another student has been a challenge. But when we sorted out the disagreements we continued as a stronger team. To work together with someone else is something I strongly recommend. You develop faster and complement each other."
ED:	"I knew from earlier experiences during the program that I am good at working in teams and therefore I felt good about working alone with the thesis."

Figure 5. Quotes from students, statements on theme 3

Theme 4: Skills and abilities regarding communication, based on goal number 9

9. Demonstrate an ability to clearly present and discuss their conclusions and the knowledge and arguments behind them, in dialogue with different groups, orally and in writing, in national and international contexts. (CDIO-Syllabus 3.2-3.3)

Table 5.
Number of reflection documents with one or several statements on theme 4

Learning outcomes	Applied Physics and Electrical Engineering (Y)	Computer Science and Engineering (D)	Electronics Design Engineering (ED)	Media Technology (MT)
Communication	26	9	4	6

All students have to write a Master's thesis and to orally present and defend it in public. Some of the students reported that they experienced some problems to finish the report in time but very few had serious problems with writing the report. Several of the thesis reports were written in English.

Y:	"My communication skills are good because it improved a lot through the project courses within the program"
Y:	"The CDIO-course was a good beginning to write more extensive reports. Perhaps it should be in English so this too is practiced".
D:	"Many of the courses within the program have given opportunities to practice both oral presentation and written reports."

Figure 6. Quotes from students, statements on theme 4

Theme 5: Judgments and approach regarding societies' needs based, on goals number 7, 10 and 11

7. Demonstrate an ability to develop and design products, processes and systems taking into account people's situations and needs and society's objectives for economically, socially and ecologically sustainable development; (CDIO-Syllabus 4.1–4.6)

10. Demonstrate an ability to make assessments, taking into account relevant scientific, social and ethical aspects, and demonstrate an awareness of ethical aspects of research and development work; (CDIO-Syllabus 1.1–1.3, 2.5, 4.6)

11. Demonstrate insight into the potential and limitations of technology, its role in society and people's responsibility for its use, including social and economic aspects, as well as environmental and work environment aspects; (CDIO-Syllabus 1.2, 1.3, 2.5, 4.1, 4.6)

Table 6.
Number of reflection documents with one or several statements on theme 5

Learning outcomes	Applied Physics and Electrical Engineering (Y)	Computer Science and Engineering (D)	Electronics Design Engineering (ED)	Media Technology (MT)
Society objectives	3	1		1
Sustainable development				
Ethical aspects				

Very few students commented on these learning outcomes. This can be interpreted in two ways: the components were missing or the students did not pay attention to this during their education. Either way, the programs must be strengthened in regard to these learning outcomes. Quotes from students:

Y: “The thesis work has given an example on what the need from labor market is but many other problems are still to be addressed. Society also put demands on the development of products/solutions to be less expensive and still at high quality.”
D: “Efforts are made to make the products easier to understand, based on the societal demands.”
MT: “I have been working with prototypes to generate an application that works best in for a particular user.”

Figure 7. Quotes from students, statements on theme 5

Theme 6: Understanding of life-long learning, based on goal number 12

12. Demonstrate an ability to identify their need of further knowledge and to continuously upgrade their capabilities. (CDIO-Syllabus 2.4, 2.5)

Table 7.
Number of reflection documents with one or several statements on theme 6

Learning outcomes	Applied Physics and Electrical Engineering (Y)	Computer Science and Engineering (D)	Electronics Design Engineering (ED)	Media Technology (MT)
Life-long Learning	21	7	3	4

Many students claimed that they have to deepen their knowledge in certain tasks and to find out more about the specific problem they were working with but also that the program trained the skill to learn more.

Y: “The various tools to problem solving that I have learnt made it smooth to understand new methods, tools, standards and practices.”
D: “I know I have made progress to understand scientific articles. I don´t think I can use this in my future work, but I will benefit from the ability to learn new subjects quickly.

Figure 8. Quotes from students, statements on theme 6

Overall summation on the thesis work

Finally some of the students had also made an overall summation regarding the thesis work in relation to the program’s learning outcomes. The following statements are quotes:

ED: “Deeper mathematical and technical knowledge and skills were a requirement to be able to do my thesis. I had to show creativity and responsibility. I also had to be able to quickly familiarize with new knowledge, judge it and use it in a new way. I communicated and presented the work for other international groups at the company.”

ED: “The thesis work has involved the whole process from idea to product, test and operating.”

MT: “I feel prepared for my future career, eager and motivated to start working. Sometimes I feel afraid that I do not know enough, but the experience of the thesis tells me that it is obvious that it will go well.”

Y: “I know I have extensive knowledge which made it possible to gain knowledge in other scientific areas needed for the thesis work. Though I know my knowledge is good I feel as I know less now than before the thesis work probably because I am more humble now by the problems you may have to face. I don´t think my personal qualities have been developed”

D: “I have never programmed in C # but I learned quickly, thanks to prior knowledge. Thanks to the way I learned to work, I've been able to solve several problems for the company, some that have existed for years.”

Y: “The problem area of the thesis is very fun and it is on the edge of technology. If I in my future career would start working on this, I think I'd feel well prepared. I do anyway, in the current situation.”

Y: “Finally we can note that both we and the company are satisfied with the result of the thesis work. We feel well prepared for our future careers.”

Figure 9. Quotes from students, statements from the overall summation

CONCLUSIONS AND LESSONS LEARNED

This pilot study includes just a subset of all submitted reflection documents.

The conclusion is that using this method of analyzing this type of data is one way to identify evidence to prove that the learning outcomes are met and where potential shortcomings occur, at least from the students’ point of view. This implicates that the reflection document connected to the Master´s thesis can be used as a supplementary tool to produce evidence used in the self-evaluation and in the continuous quality work of the program boards.

Since the template for the reflection document is quite open and the classification of the themes is aggregated, both could be refined to produce more specific data. However, the effort required to change these has to be considered, in relation to the outcome. The method used provides a structured basis that justifies drawing conclusions regarding the fulfillment of learning outcomes.

DEVELOPMENT AND MAINTENANCE

The next step is to review and analyze the remaining data. This study covers programs within related subject areas. When all programs at the faculty are included there is a possibility to see if there are any perceived differences between them.

To use this tool in quality work and program development, an analysis should be performed on a regular basis. The method is time consuming, and it is still to be decided how often such an analysis should be performed. It would probably not be necessary more often than biannually.

REFERENCES

[1] Bankel J., Berggren K.-F., Crawley E., Engström M., El Gaidi K., Östlund S., Soderholm D. and Wiklund I., "Benchmarking Engineering Curricula with the CDIO Syllabus", The International Journal of Engineering Education, Vol. 21, No. 1, 2005, pp 121-133.

[2] Bankel J., Berggren K.-F., Blom K., Crawley E. F., Östlund S. and Wiklund I., "The CDIO Syllabus: A comparative study of expected student proficiency", The European Journal of Engineering Education, Vol. 28, No. 3, 2003.

[3] Gunnarsson S., Wiklund I., Svensson T., Kindgren A., and Granath S., "Large scale use of the CDIO Syllabus in formulation of program and course goals", 3rd International CDIO Conference, 2007.

[4] Malmqvist J., Östlund S. and Edström K., "Integrated Program Descriptions – A Tool for Communicating Goals and Design of CDIO Programs", 2nd International CDIO Conference.

[5] Sparsö J., Klit P., May M., Mohr G. and Viglid M.E., "Towards CDIO-based B.eng studies at the Technical University of Denmark", 3rd International CDIO Conference, 2007.

[6] Gunnarsson S., Herbertsson H., Kindgren A., Wiklund I., Willumsen L. and Viglid M.E., "Using the CDIO Syllabus in Formulation of Program Goals – Experiences and Comparisons", 5th International CDIO Conference.

[7] Edwardsson Stiwne E. and Jungert T., "Engineering Students Experiences of the Transition from Study to Work", 3rd International CDIO Conference, 2007.

[8] Svensson T. and Krysander C. (2011) Project Model LIPS. Studentlitteratur, Lund, 2011. ISBN 9789144075266.

[9] General Guidelines for Self-Evaluation in the Swedish National Agency for Higher Education´s Quality Evaluation System 2011—2014, Stockholm, Högskoleverket, 2011:11 R. Available at <www.hsv.se>.

[10] Sadurskis A., "Quality Assurance of Engineering Education in Sweden", 1st International CDIO Conference.

[11] Lux Examination Review: Handledning för korsvis utvärdering av examensarbeten (in Swedish), Linköping University & Umeå University, 2010. Available at <www.liu-umu.se/download/lux-handledning-utvardering-examensarbeten.pdf>

[12] Gunnarsson S., Lindblad E., and Wiklund I., "Using an alumni survey as a tool for program evaluation", 1st Annual CDIO Conference, Kingston, Ontario, Canada, 2005.

[13] Berggren K.-F., Svensson T., Gunnarsson S., and Wiklund I., "Development of the Applied Physics and Electrical Engineering (Y) Program at Linköping University through the participation in the CDIO Initiative", 8th UICEE Annual Conference on Engineering Education, Kingston, Jamaica, 2005.

[14] Study Guide 2012, Institute of Technology, Linköping University <www.lith.liu.se/sh/sh2012>

[15] Hsiu-Fang H. and Shannon S.E., "Three Approaches to Qualitative content Analysis", Qual Health Res November 2005.

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APPENDIX 1

The Higher Education Ordinance: Annex 2 Qualifications ordinance (Excerpt)
<www.hsv.se/lawsandregulations/thehighereducationordinance.4.5161b99123700c42b07ffe3981.html >

Degree of Master of Science in Engineering [Civilingenjörsexamen]

Scope

A Degree of Master of Science in Engineering is awarded after the student has completed the courses required to gain 300 credits.

Outcomes

For a Degree of Master of Science in Engineering the student shall demonstrate the knowledge and skills required to work autonomously as a graduate engineer.

Knowledge and understanding

For a Degree of Master of Science in Engineering the student shall

(1) demonstrate knowledge of the disciplinary foundation of and proven experience in his or her chosen field of technology as well as insight into current research and development work, and
(2) demonstrate both broad knowledge of his or her chosen field of technology, including knowledge of mathematics and the natural sciences, as well as a considerable degree of specialised knowledge in certain areas of the field.

Competence and skills

For a Degree of Master of Science in Engineering the student shall

(3) demonstrate the ability to identify, formulate and deal with complex issues autonomously and critically and with a holistic approach and also to participate in research and development work and so contribute to the formation of knowledge
(4) demonstrate the ability to create, analyse and critically evaluate various technological solutions
(5) demonstrate the ability to plan and use appropriate methods to undertake advanced tasks within predetermined parameters
(6) demonstrate the ability to integrate knowledge critically and systematically as well as the ability to model, simulate, predict and evaluate sequences of events even with limited information
(7) demonstrate the ability to develop and design products, processes and systems while taking into account the circumstances and needs of individuals and the targets for economically, socially and ecologically sustainable development set by the community
(8) demonstrate the capacity for teamwork and collaboration with various constellations, and
(9) demonstrate the ability to present his or her conclusions and the knowledge and arguments on which they are based in speech and writing to different audiences in both national and international contexts.

Judgement and approach

For a Degree of Master of Science in Engineering the student shall

(10) demonstrate the ability to make assessments informed by relevant disciplinary, social and ethical aspects as well as awareness of ethical aspects of research and development work
(11) demonstrate insight into the possibilities and limitations of technology, its role in society and the responsibility of the individual for how it is used, including both social and economic aspects and also environmental and occupational health and safety considerations, and
(12) demonstrate the ability to identify the need for further knowledge and undertake ongoing development of his or her skills.

Independent project (degree project)

A requirement for the award of a Degree of Master of Science in Engineering is completion by the student of an independent project (degree project) for at least 30 credits.

Miscellaneous

Specific requirements determined by each higher education institution itself within the parameters of the requirements laid down in this qualification descriptor shall also apply for a Degree of Master of Science in Engineering.

APPENDIX 2

CDIO-syllabus, LiTH version

1. MATHEMATICAL, SCIENTIFIC AND TECHNICAL KNOWLEDGE
- 1.1 KNOWLEDGE OF UNDERLYING SCIENCES AND MATHEMATICS
- 1.2 KNOWLEDGE IN CORE ENGINEERING
- 1.3 ADVANCED KNOWLEDGE IN ENGINEERING

2. PERSONAL AND PROFESSIONAL SKILLS AND ATTRIBUTES
- 2.1 ENGINEERING REASONING AND PROBLEM SOLVING
  - 2.1.1. Problem Identification and Formulation
  - 2.1.2. Modeling
  - 2.1.3. Estimation and Qualitative Analysis
  - 2.1.4. Analysis with Uncertainty
  - 2.1.5. Solution and Recommendation
- 2.2 EXPERIMENTATION AND KNOWLEDGE DISCOVERY
  - 2.2.1. Hypothesis Formulation
  - 2.2.2. Survey of Print and Electronic Literature
  - 2.2.3. Experimentel Inquiry
  - 2.2.4. Hypothesis Test and Defence
- 2.3 SYSTEM THINKING
  - 2.3.1. Thinking Holistically
  - 2.3.2. Emergence and Interactions in Systems
  - 2.3.3. Prioritization and Focus
  - 2.3.4. Trade-offs, Judgements and Balance in Resolution
- 2.4 PERSONAL SKILLS AND ATTITUDES
  - 2.4.1. Initiative and Willingness to Take Risks
  - 2.4.2. Perseverance and Flexibility
  - 2.4.3. Creative Thinking
  - 2.4.4. Critical Thinking
  - 2.4.5. Awareness of One's Personal Knowledge, Skills and Attitudes
  - 2.4.6. Curiosity and Life-Long Learning
  - 2.4.7. Time and Resource Management
- 2.5 PROFESSIONAL SKILLS AND ATTITUDES
  - 2.5.1. Professional Ethics, Integrity, Responsibility and Accountability
  - 2.5.2. Professional Behaviour
  - 2.5.3. Proactively Planning for One's Career
  - 2.5.4. Staying Curren on World of Engineer

3. INTERPERSONAL SKILLS: TEAMWORK AND COMMUNICATION
- 3.1 TEAMWORK
  - 3.1.1. Forming Effective Teams
  - 3.1.2. Team Operation
  - 3.1.3. Team Growth and Evolution
  - 3.1.4. Leadership
  - 3.1.5. Technical Teaming
- 3.2 COMMUNICATIONS
  - 3.2.1. Communications Strategy
  - 3.2.2. Communications Structure
  - 3.2.3. Written Communication
  - 3.2.4. Electronic/Multimedia Communication
  - 3.2.5. Graphical Communication
  - 3.2.6. Oral Presentation
- 3.3 COMMUNICATIONS IN FOREIGN LANGUAGES
  - 3.3.1. English
  - 3.3.2. Languages of Regional Industrialized Nations
  - 3.3.3. Other Languages

4. CONCEIVING, DESIGNING, IMPLEMENTING, OPERATING AND COMMERCIAL REALIZATION OF TECHNICAL PRODUCTS, SYSTEMS AND SERVICES WITH THE ENTERPRISE AND SOCIETAL NEEDS AND REQUIREMENTS

4.1 SOCIETAL CONDITIONS, INCLUDING ECONOMIC, SOCIAL AND ECOLOGICAL SUSTAINABILITY.

- 4.1.1. Roles and Responsibility of Engineers
- 4.1.2. The Impact of Engineering on Society
- 4.1.3. Society's Regulations of Engineering
- 4.1.4. The Historical and Cultural Context
- 4.1.5. Contemporary Issues and Values
- 4.1.6. Developing a Global Perspective
- 4.1.7 The engineer's role and the need for economically, socially and ecologically sustainable development.

4.2 ENTERPRISE AND BUSINESS CONTEXT

- 4.2.1. Appreciating Different Enterprise Cultures
- 4.2.2. Enterprise, Strategy, Goals and Planning
- 4.2.3. Technical Entrepreneurship
- 4.2.4. Working Successfully in Organizations

4.3 CONCEIVING AND ENGINEERING SYSTEMS

- 4.3.1. Setting System Goals and Requirements
- 4.3.2. Defining Function, Concept and Architecture
- 4.3.3. Modeling of System and Ensuring Goals Can Be Met
- 4.3.4. Development Project Management

4.4 DESIGNING SYSTEMS

- 4.4.1. The Design Process
- 4.4.2. The Design Process Phasing and Approaches
- 4.4.3. Utilization of Knowledge in Design
- 4.4.4. Disciplinary Design
- 4.4.5. Multidisciplinary Design
- 4.4.6. Multi-Objective Design

4.5 IMPLEMENTING SYSTEMS

- 4.5.1. Designing the Implementation Process
- 4.5.2. Hardware Manufacturing Process
- 4.5.3. Software Implementing Process
- 4.5.4. Hardware Software Integration
- 4.5.5. Test, Verification, Validation and Certification
- 4.5.6. Implementation Management

4.6 OPERATING

- 4.6.1. Designing and Optimizing Operations
- 4.6.2. Training and Operations
- 4.6.3. Supporting the system Life Cycle
- 4.6.4. System Improvement and Evolution
- 4.6.5. Disposal and Life- End Issues
- 4.6.6 Operation Management