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Published in:
Proceedings of the 11th International CDIO Conference

Publication date:
2015

Document Version
Publisher's PDF, also known as Version of record

Developing merged CDIO based curricula for diploma (B.Eng.) IT study programs at DTU

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ABSTRACT

Starting 2007, the Danish government drew up a new map of universities through a process of mergers of a number of universities and research institutions (UFM 2007), as part of the national innovation strategy. In the beginning of 2013, the Engineering College Copenhagen (IHK, now DTU Ballerup) merged with the Technical University of Denmark (DTU Lyngby). The goal of the merger was to educate ever more innovative diploma engineers to fulfill the needs by Danish industry through combining a practice-oriented development environment and a research-oriented environment.

Merging a university with an engineering college implies merging two different cultures: established teaching staff, different study lines; a difficult undertaking at best. Existing study lines must be merged, overlaps and differences identified and handled, and in general a common understanding and language must be established.

The two institutions represented before the merger well 3500 B.Eng. students. The goal of the merger was to combine the best of the existing educations rooted in a practice-oriented development environment and a research-oriented environment. At the same time, the merger was supposed to contribute to the national innovation strategy.

In this paper we describe the process of developing new, merged B.Eng curricula in the IT field (Diploma IT), as part of the merger between DTU Lyngby and IHK. Particular attention will be given to the following subjects:

- The design process used to develop the new merged study programs;
- Involvement of stakeholders in designing the new curricula;
- Introduction of a common interdisciplinary innovation course in the programs; and
- Education of teaching staff: Integration into one organization.

KEYWORDS

CDIO-based study programs, Stakeholder involvement, Innovation.
Standards: 1, 2, 3, 6, 8, 9, 11

INTRODUCTION

Since 2008, all B.Eng. programs at DTU are CDIO-based (Sparsø et. al. 2007), and a lot of experience with this has been obtained in the process of implementing CDIO. As part of this process, also IT diploma programs at DTU Lyngby have been CDIO-based.

IT diploma programs at IHK Ballerup have not as such been CDIO based prior to the merger. Similar elements, for example, multi-disciplinary projects, have been used in their education.

The study programs both in Lyngby and Ballerup consist of 7 semesters, of which the first four semesters contain compulsory activities. Each of these compulsory semesters contains an interdisciplinary project. This foundational phase is followed by elective activities on the 5th semester, an internship in an engineering company (Nyborg et al, 2012) on the 6th semester, and the final project on the 7th semester, again in collaboration with an engineering company.

To ease the merger, study line development groups were set up for the development of new study programs based on the existing ones. These groups included the following key stakeholders: teachers, students on current courses, graduates, and employers.

Starting from earlier study lines at DTU Lyngby and IHK, which basically embraced computer systems engineering and IT and Economics, and based on relevance and expected intake, a total of 3 merged programs within the IT field were proposed:

- Software technology (SWT) is a pure software-oriented study program;
- IT and Economics (ITOE) combines software development and economics; and
- IT Electronics (ITEL) is a computer systems engineering education.

The contents of the new study programs are based on the previous study lines from the two campuses, as well as input from stakeholders. For example, stakeholders stressed the need for testing and test methods on software systems, which had not been covered systematically in the compulsory courses of the former programs. This request resulted in changes to especially the SWT and ITOE study lines.

THE DESIGN PROCESS

The design process for the new study lines during the merger began with a joint meeting between the two organizations in autumn 2012, where existing study lines were reviewed. As mentioned in the introduction, IHK did not implement CDIO but had similar elements in their programs, whereas DTU Lyngby since 2008 has had CDIO-based programs. Both IHK and DTU Lyngby offered IT-related study lines before the merger, and they all contained elements in both software and hardware development.

The study lines at DTU Lyngby were IT (computer systems engineering) and IT and Economics, both developed and described according to the CDIO syllabus with focus on all categories in the syllabus. The IT-related study lines at IHK Ballerup also included for example a computer systems engineering line. As mentioned, this study line contained elements similar to CDIO, but did not follow or implement the CDIO syllabus. Overall the existing elements mostly addressed syllabus category 1; categories 2,3, and 4 were only addressed indirectly, since each semester contained a joint project where these skills came into play.

Based on talks with stakeholders and input from students, it soon became clear that there was a need for a new direction in computer systems engineering, as this subject was not treated deeply enough in the existing IT study lines. Also, there was a desire to expand the teaching of pure software development on the existing IT directions.

The study line in IT and Economics at DTU Lyngby, started in 2007, is offered in collaboration with the Copenhagen Business School (CBS). The program originated from a specific request from stakeholders to educate engineers who in addition to technical knowledge in IT also have knowledge of economic fundamentals, and consequently it was developed together with the computer systems engineering study line at DTU Lyngby, with which it shares the software-related education elements. As part of the merger it was agreed that this direction should continue.

The conclusion of the discussions during the initial phase of the merger between DTU Lyngby and IHK was the creation of the study lines mentioned above:

- SWT based on the earlier computer systems engineering lines where the hardware part is removed and replaced by software development related topics;
- ITEL based on the earlier computer systems engineering lines with hardware focus on systems engineering; and
- ITOE based on the earlier computer systems engineering lines with some computing science topics replaced by economics.

Another important aspect of merging two educational organizations is the question of semester structures; during the merger it was decided to adapt the structure from DTU Lyngby, where a semester consists of a 13 week period with several lectures equaling 25 ECTS points, and a 3-week period full time studies with a single lecture equaling 5 ECTS points.

Once all these initial discussions had been finalized, study line development groups were formed with the aim to design the curricula for the individual study lines. DTU Lyngby had already collected a lot of experience in integrated curriculum design as part of the earlier adaption of the CDIO standards throughout its B.Eng. studies, and could therefore act as a mentor for staff from IHK. The overall curriculum design process followed by these groups is shown in Figure 1.

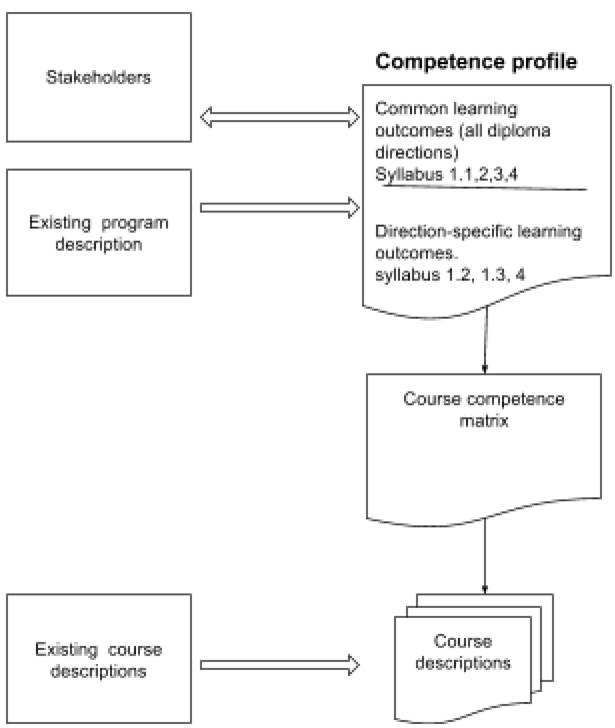

Figure 1: The curriculum design process

It was agreed to use a top-down approach, but also to use previous material (program and course descriptions) to the extent appropriate.

The key document which forms the basis for the design itself is the competence profile. For each study line, a competency profile was defined, which consists of a common set of learning outcomes (common to all diploma study lines at DTU), and a set of study line-specific learning outcomes. DTU has defined 20 common overall learning outcomes within CDIO syllabus categories 1.1, 1.2, 2, 3 and 4 to standardize common learning outcomes within these categories across all diploma study lines.
The task of the working groups was to define learning outcomes within the competence categories 1.2 and 1.3 (advanced engineering fundamental knowledge) for each study line. Also a number of common learning outcomes for the three study lines, particularly SWT and ITOE, have some inherent overlap. Stakeholders were involved in the definition of the study line-specific learning outcomes. We have chosen to divide stakeholders into two groups: Companies employing candidates from the study line, and former graduates.
In the fall of 2013 the first meeting was held with the stakeholders. Annual meetings are planned to continuously validate the programs and make required adjustments to meet stakeholder expectations. At the first meeting, the competence profile was presented for the three study lines and we got the following very useful inputs for further design:

- General process understanding: Testable requirements, systematic version control;
- Aspects of IT Security as part of the programme: all students know OWASP (Open Web Application Security Project, www.owasp.org);
- More about scripting technologies (html, css and javascript); and
- In addition to professional knowledge, students must have a flair for leadership, take responsibility, understand project work, be innovative, make tangible systems, think and work globally.

As a result of input from the stakeholders we introduced new learning objectives in the competence profiles and a new course in version control- and test methods for SWT and ITOE. In addition, we created a new course in Innovation on the 5th semester for all study lines.
Based on the competence profiles, a course portfolio was proposed, where each course contributes to achieving the final competences. Parts of the curriculum descriptions from previous programs were used to the extent appropriate. A course competence matrix was drafted for each study line. The course competence matrix maps learning outcomes from the competence profile to the courses to a specific Bloom level. The format of this matrix is shown in Table 1.

Table 1. Structure of the course competence matrix. The common learning outcomes together with study line specific outcomes forms DTU’s customized CDIO syllabus

	Learning outcomes	Common (20 outcomes)	Study line specific outcomes (SWT: 15, ITOE: 14, ITEL: 12)
Semester	Course		
1	1xxx	Bloom levels	Bloom levels
	..	Bloom levels	Bloom levels
2	2xxx	Bloom levels	Bloom levels
...	…...	….	….

Workshops

Based on the work of the study line development groups, two workshops were held with teaching staff from Lyngby and Ballerup. The purpose of these workshops was:

- Presentation of course competence matrices, and discussion of Bloom levels;
- Presentation of "coarse" course descriptions as basis for detailed descriptions;
- Preparation of detailed course descriptions, including learning outcomes which meet Bloom levels in the course competence matrix; and
- Discussion of possible design-build project in each semester.

One of the challenges we encountered was to get the teaching staff to include common learning objectives in the syllabus categories 2 and 3 in the course descriptions, as this was new for some of them.

COMMON LEARNING OUTCOMES

Tables 2.1, 2.2, 2.3 and 2.4 show the customized DTU common learning outcomes mapped to the syllabus categories together with the Bloom levels obtained. The Bloom taxonomy levels we use are:

1. knowledge, 2. understand, 3. apply, 4. analyze, 5. evaluate.

The academic learning outcomes are not shown, since it is not considered to be relevant for this conference.

Table 2.1. Syllabus category 1.1 and 1.2: Mathematical science and fundamental technical-disciplinary engineering

Learning outcome	Bloom level
1. has a solid application oriented knowledge and can independently apply basic scientific, mathematical, statistical, IT and technological principles, theories and methods based on the latest developments and research for solving practical engineering problems	3
2. understand the interrelationship between different disciplines theory in the practical design of technological solutions	2
3. can evaluate practical and theoretical issues on both a global and detailed level and justify the choice of solution models	5
4. can, based on the theoretical basis, select and apply appropriate modeling and simulation methods and produce detailed evidence	4
5. can select and apply appropriate analytical methods and produce detailed evidence	4

Table 2.2. Syllabus category 2: Personal and professional competencies

Learning outcome	Bloom level
6. can apply engineering ethical principles and principles of sustainability (people, planet and profit) in solving technological problems	3
7. can apply subject-related information sources and perform relevant and critical information searching	4
8. can acquire new knowledge through reflection and critical thinking in order understand and master the subject areas	5
9. master a technical technical language in Danish and technical terminology in English and can read the relevant technical literature in both languages	3
10. can present problems and solutions both in writing and orally to different types of stakeholders	4
11. can take responsibility for own learning and continued competence development	2

Table 2.3. Syllabus category 3: Interpersonal skills

Learning outcome	Bloom level
12. can work independently and in groups and are able to structure a larger work, including keeping schedules, organize and plan the work	4
13. can be part of cooperation and managerial functions and relationships on a qualified basis with people who have different educational, linguistic and cultural background	4

Table 2.4. Syllabus category 4: Profession oriented competences

Learning outcome	Bloom level
14. is holistic in solving specific technical problems covering all phases of CDIO (Conceive, Design, Implement, Operate) from problem identification, idea generation and specification of requirements, the design, optimization and implementation to actual production and deployment	5
15. have knowledge of relevant industrial procedures and standards	1
16. can include social, economic, environmental and safety consequences in the solution of engineering tasks	4
17. can apply the principles of sustainability (people, planet and profit) to evaluate and select a process, product or system	5
18. can work with innovative processes and may include core business economy in practice	3
19. Can use existing technological knowledge in new and creative ways in solving practical engineering problems, be it a new or improved process, product or system that generates added value for the originator of the task	3
20. have a basic business understanding	2

CURRICULUM PLANS

The initial main result of the working groups established were the study plans for the compulsory first four terms of the study lines; these are presented in this section. The three study lines discussed here naturally share many core elements. All three study plans were designed in parallel, sharing a common skeleton complemented by study line-specific

elements. A side effect of this approach is that students can shift between study lines in the early stage of their studies without losing too much time.
Another important element of the 3 study lines presented is the joint CDIO project on the 4th semester (Bolander et. al. 2007). To strengthen collaborative skills, students from all IT study lines are given the opportunity to work together on a common project. This common CDIO course leads to a new 10 ECTS course in innovation on the 5th semester, which is compulsory for all diploma study lines at DTU and will integrate students from all other study lines. The idea behind this course is to give students the opportunity to collaborate on inter-disciplinary projects. This course strengthens not only innovation skills but personal and interpersonal skills as well.

Study Plan - Common Elements

The study plans of all three study lines share a number of elements. For all three lines, the 5th semester contains elective courses and the new 10 ECTS innovation course, followed by an internship on the 6th semester, and 10 ECTS electives and the final project on the 7th term. Also, all three study lines feature CDIO projects of some kind in each semester, ranging from simple design-implement projects in the first semester to a “pure” CDIO course on the 4th semester. In addition to these similarities, a number of other similarities are found:

- SWT and ITOE share the development and tool courses, as well as advanced programming and data structure courses; and
- SWT and ITEL share many of the advanced courses on third and fourth semester.

The students of the three study lines have slightly different competence profiles, which is exploited in the common CDIO course on the 4th semester and ultimately in the innovation course on the 5th semester. The economics skills of ITOE students, for example, are unique in this mix, and complement the competences of the more technical oriented students.

Study Plan - SWT

As mentioned above, the SWT study line is based on the original computer systems engineering lines at DTU Lyngby and IHK. As a result of the merger and based on discussions with the group of stakeholders, the hardware-related courses were removed (but are still available as electives), and replaced with deeper courses on software development. New courses implemented based on industry demands are those on version control and testing as well as software for mobile devices.

Table 3. Study Plan - SWT

term	5 ECTS	5 ECTS	5 ECTS	5 ECTS	10 ECTS
1	Mathematics	Discrete Math	Development Methods	Version control and testing	Introductory programming
2	Database programming	Algorithms and data structures	Data communication	Networking lab	Advanced programming
3	Statistics	Compilers	Game physics	Object-oriented analysis & design	Software for Mobile Devices
4	Operating systems	Distributed systems	Model-based software dev.	Parallel systems	CDIO

Study Plan - ITOE

The study line on ITOE is characterized by the mix between courses from the SWT line and courses offered by the Copenhagen Business School. The programming courses are shared in a light version, with focus on business-relevant skills, and are complemented by the economics courses. During the elective phase, students can choose also from courses offered by the business school to further deepen their knowledge in this area.
The courses marked in bold below are shared with the SWT study line. By mixing students from SWT and ITOE, each group learns early to interact with students from different backgrounds, and to make use of different skill sets.

Table 3. Study Plan - ITOE

term	5 ECTS	5 ECTS	5 ECTS	5 ECTS	10 ECTS
1	**Version control and testing**	**Introductory programming**	**Development Methods**	Managerial Economics, Company Economics	
2	**Database programming**	Project in software dev.	**Mathematics**	Managerial Economics, Company Law	
3	**Statistics**	**Discrete Math**	Data communication	**Object-oriented analysis & design**	**Software for Mobile Devices**
4	**Algorithms and data structures**	**Distributed systems**	**Model-based software dev.**	**Advanced programming**	**CDIO**

Study Plan - ITEL

As part of the merger, the study plan of the originally embedded systems-oriented study lines was re-designed to make the computer systems engineering aspects more explicit. This resulted in the progression from simple embedded systems over digital systems assembled of components to the programming of these components.

The courses marked in bold below are shared with the SWT study line. By mixing SWT and ITEL students, the software students get a deeper knowledge of hardware-related issues and programming, and the hardware students learn about advanced programming techniques.

Table 4. Study Plan - ITEL

term	5 ECTS	5 ECTS	5 ECTS	5 ECTS	10 ECTS
1	Mathematics	Systems programming		Digital Electronics	Introduction to embedded systems
2	Object-oriented programming	**Algorithms and data structures**	**Data communication**	**Networking lab**	Digital Systems
3	**Statistics**	**Compilers**	Security of Embedded Systems	Signal Analysis	HW/SW programming
4	**Operating systems**	**Distributed systems**	Control theory	**Parallel systems**	**CDIO**

EDUCATION OF STAFF: INTEGRATING INTO ONE ORGANIZATION

The merger between the university and the engineering college meant bringing together an institution with a long record of CDIO-based education with an institution not based on the CDIO standards. The aim was to integrate the engineering college into the university as being the main contributor of teaching on the bachelor of engineering degrees:

- Establishing a coherent and joint view on engineering education based on the principles of CDIO;
- Raising the level of mathematics and natural sciences in the curricula; and
- Integrating B.Eng. teaching and students into the university.

In this process, the mutual respect of the differences between two organizations has to be balanced with the overall aim of a single, joint organization.
A comprehensive education plan was set up for all teachers of the engineering college introducing the principles of CDIO, including the adaption of rules etc. of the university. The plan was composed as three workshops attended by all college teachers. During the workshops, the previously developed DTU CDIO handbook was used as a reference:

- A first workshop introduced CDIO-based education, including the CDIO standards and syllabus. Specific attention was given to spread the university view on learning aims, including the use of the Bloom taxonomy. Course description etc from the development groups were considered during this workshop.
- The second workshop focused on the competency matrix. The competency matrices of the three study lines in Table 1 were used as the basis of the teaching. The matrices were analyzed in detail both along horizontal and vertical tracks, with emphasis of the role of each individual class and on the coherence of semesters and the progression over semesters.

- A third workshop covered forms of education and of evaluation (Standards 8 and 11). Reverting to the results of the development groups, the individual classes were reviewed and analyzed with respect to the teaching forms and the coherence in a semester.

Raising the level of mathematics is an effort mainly addressed in the study plan development, while consequences of this are recognized in integration process. A common understanding on the implementation of CDIO standards is established through educating the teaching staff. More detailed integration of staff is still required: E.g. obtaining a common view on semester coherence.
Both institutions were familiar with a semester structure consisting of a 13-week teaching period followed by a 3-week project period. During the 13-week period, several classes are taught, while the 3-week period contains only a single, coherent project activity.
Traditionally at the engineering college, the classes of the 13-week period were loosely connected to the 3-week project period. Each class would define a problem, part of a common theme, and its solution postponed to the 3-week project period. While this approach made teaching the classes of each semester less interdependent, a disadvantage is that the common theme of the semester only became evident to the student upon completion of the semester.
The new CDIO-based curricula contain a team-based multi-disciplinary engineering project each semester and/or design-build projects creating a horizontal coherence of each semester. A semester is planned of disciplinary classes in which one class is designated as CDIO project carrier course (CDIO carrier), typically occupying the 13-week and the 3-week period of the semester. The CDIO carrier, in addition to its academic contribution to the curriculum, forms the frame of the common semester project. During the mono-disciplinary classes, students work on sub-projects, which later become part of the semester-project, fully integrated into and evaluated as part of the CDIO carrier. The sub-projects imply closer coordination between classes of the semester.

CONCLUSION AND FINAL REMARKS

Almost two years have passed since it was decided to merge DTU Lyngby with the Engineering College Copenhagen. This may sound like a long time, but changing people's attitudes takes time.
The new programs were launched in September 2014. Starting fall 2014, teachers from Ballerup and Lyngby participated in the teaching of all three study lines and have thus gained experience in collaboration in running a joint design-build project of the semester.
Our recommendations to others who intend to go through a similar process are:

- Spend time explaining syllabus, especially to relate this to the existing program descriptions; and
- Give examples of running a specific semester with design-build projects (Nyborg et. al. 2010).

Despite these efforts, we believe that there is still some way to go before CDIO becomes a natural part of the merged organization.

REFERENCES

Bolander T., Fischer P., Hansen. T. K. (2007), From Frustration to Success: A Case-Study in Advanced Design-Build Experiences. *Proceedings of the 7th International CDIO Conference, Technical University of Denmark, Denmark, June 20-23, 2011.*

Nyborg M., Høgh S., Lauridsen P. (2012). Evaluation of the industrial internship for the Diploma IT programme at DTU. *Proceedings of the 8th International CDIO Conference, Queensland University of Technology, Brisbane, Queensland, Australia, July 2nd to 4th, 2012*

Nyborg M., Høgh S. (2010) Mapping an industrial IT project to a 2nd semester design-build project. *Proceedings of the 6th International CDIO Conference, Ecole Polytechnique, Montreal, June 15-18, 2010.*

Sparsø J., Bolander T., Fischer P. Høgh S., Nyborg M., Probst C.W., Todirica E.A. (2011). CDIO projects in DTU's B.Eng. in IT study program. *Proceedings of the 7th International CDIO Conference, Technical University of Denmark, Denmark, June 20-23, 2011.*

Sparsø J., Klit P., May M., Mohr G,, Vigild M.E. (2007), Towards CDIO-based B.Eng. studies at the Technical University of Denmark. *Proceedings 3rd International CDIO Conference, 2007.*

Todirica E.A., Probst C.W. (2014). Mind the gap - teaching computer and compiler design in lockstep. *Proceedings of the 10th International CDIO Conference, UPC, Spain, June 15-19, 2014.*

UFM (2007), University mergers of 2007. *The Ministry of Higher Education and Science*
http://ufm.dk/en/education-and-institutions/higher-education/danish-universities/the-universities-in-denmark/university-mergers-of-2007

BIOGRAPHICAL INFORMATION

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