KEY-FACTORS FOR A SUCCESSFUL CDIO IMPLEMENTATION IN A DANISH CONTEXT

Jens Bennedsen

Aarhus University, School of Engineering

Mette Birkedahl Christensen

Aarhus University, School of Engineering

ABSTRACT

This article describes factors that promote a good CDIO implementation. The article is based on interviews with key players in all the Danish CDIO collaborators on their views of the CDIO implementation process. It describes six factors that all found enabled the CDIO implementation: Management support, Evolution, not revolution, Common language, Program view, competence matrix and Support. The article further more describes some elements of the Danish engineering education culture that helped the implementation of CDIO at these given institutions.

KEYWORDS

Implementation, Success factors, Denmark

INTRODUCTION

In Denmark, three institutions are member of the CDIO initiative and one additional institution is actively considering applying. The institutions are different, one has been member for a long time, one has just joined, one is a university with a problem- and project based pedagogy, one has just merged with a big university. This article identifies reasons for joining CDIO and describes and compares different ways of implementing CDIO at the institution.

This article addresses this problem by identifying factors that contribute to or hinder the implementation. These factors will be identified by semi-structured interviews with key players in implementing CDIO at institutions in Denmark. In this way, it can be view as a supplement to the critical success factors identified by Malmqvist et al [1]

Different levels of implementation exist. Many of the very successful stories about CDIO initiatives are based on a limited number of enthusiastic teachers and/or a limited number of study programmes. The framework for this paper is CDIO at an institutional level. The various specific engineering programs, where CDIO implementation actually takes place and often within a single program at first, like the mechanics, establishing a CDIO model for the whole institution, - is left out of sight.

METHOD

Our initial research questions centered on identifying key-factors for successful CDIO implementation in a Danish context. Following this approach we did three semi-structured interviews and one focus group interview with key players on implementing CDIO at the above mentioned institutions. The key players chosen for the interviews were all situated at a leadership level with responsibilities in learning, pedagogy and research, and not necessarily teachers as such (anymore). The single interviewees were chosen as being an active participant in CDIO initiatives at their institution and for having a pedagogical perspective in their job practice, which hopefully would give us an opportunity to see differences between institutions in this perspective. The persons we did our interviews with came from the Technical University of Denmark (DTU), Copenhagen University College of Engineering (IHK) and Aalborg University Faculty of Engineering & Science. We ourselves come from Aarhus University School of Engineering (ASE).

We had the intention to figure out to what degree the institutions were working with CDIO, from a scale of loosely associated to being more committed CDIO members. And further to identify the key-factors for their successes with CDIO implementation, made more precise by asking questions about the seven essentials out of the 12 standards. These interviews were also audio-recorded, and notes were taken during the interviews to support the subsequent analysis. The notes from the interviews are based more on interpretations of what took place than on verbatim transcriptions, but these are used as pointers into the data material, not as raw data.

The purpose of this paper is to look at some general factors in the CDIO implementation. In accomplishing this we have been focusing on some meta-cognition patterns. There exists many different implementations strategies and it is not possible to say one is better than the other, as much informal and tacit knowledge is involved. There is no simply way of making a scale once you get into the actual working of various educational programs and how experi-ced and skilled teachers improve disciplines, and why should any attempt be made. If measuring 'how far' the institutions were in the implementing process, it would have been more appropriate to look at e.g. self-evaluations of an institution's CDIO competence level in each of the 12 standards. The self-evaluations are described in [2].

THE DANISH CONTEXT

Even in a small state like Denmark the institutions vary significantly. Engineering schools were formerly independent and largely smaller institutions, at one point in time there were ten; now all except one have become part of bigger universities. Two larger engineering schools, Aarhus University School of Engineering and Copenhagen University College of Engineering, have merged and will merge with a university. This poses a challenge in the transformation process into becoming university based engineering educations as well – on a practical level – how many resources are available for implementing CDIO among other pressing tasks. A challenge that also varies according to the traditions of the particular university institution the single engineering school becomes part of.

In the MIT tradition of the CDIO initiative, engineering education was already university based, and the "deep concern" this created with a lack of certain skills, "such as teamwork, critical thinking, and social awareness", expressed by the "voice of the customer", as well as needed reforms in the undergraduate education, actually triggered part of the CDIO initiative, according to Edward F. Crawley [3]. In Denmark, you have educational set-ups where workshop training is mandatory in the first semester and a 'diploma' engineering grade, besides the bachelor program, composed of 7 semesters, one of which takes place in a business organization, is part of the educational programs offered. This half year of internship surely provides the students with an understanding of working in a business context and brings an added – also bodily – experience into the educational program. The 'diploma' engineering grade (3 ½ years) is offered at all institutions but most people follow

this line in the centre of Jylland (like at ASE) and on the island of Zealand (DTU and IHK). Other institutions primary focus is on bachelor (3 years) and 'civil' engineering programs (3 + 2 years). Besides this, the teachers at some institutions also largely have been business employed engineers before entering their teaching position, external lectures and engineers employed in business also might teach part of some programs. The possibilities for students of getting hands-on experience in design and build projects, and real life engineering situations in the educational program, is in this way much richer than one might anticipate beforehand. Certain ways of developing specific skills were already present in various programs and the institutional setup. When university fusions are now happening the engineering educational institutions are getting in closer contact with more fundamental scientific research. Thereby also coming out of, as one interviewee found, some self-feeding processes where one form of practice was informing another practice, even though there is a lot of research and development in business.

Perspectives on the engineering institutions in Denmark again refer to some engineering educations that have been part of a university for a longer period and also, of course, the various state and interstates initiatives and legislations, like the Bologna process, the 7-point grading scale, etc. A number of engineering schools also have been part of universities where unified models for educational programs were developed. At the University of Southern Denmark, not yet in collaboration with CDIO, a special model the 'Engineering Education Model of the University of Southern Denmark' (DSMI) has been developed. Another model at a CDIO collaborating University, is the full range Project Based Learning (PBL) at Aalborg University, named the Aalborg Model, applied to all study programs at this university including the engineering educations. A strong national centre and network also exists involving all engineering educational institutions, Centre for Engineering Education Research and Development (DACIN), offering for instance educational and pedagogical courses to assistant professors. DACIN even had a forerunner in the (Danish) National Pedagogical Network for Engineering Education (IPN), founded in 1996, which in similar ways influenced the development of the pedagogical tradition and models in all Danish engineering educations.

THE C-D-I-O VISION OF ENGINEERING PRACTICE
The C-D-I-O, the Conceive – Design – Implement – Operate, seems like a very successful and deep vision communicating the different steps in CDIO to newcomers and older member institutions. It's properly something we reflect but also something one might forget while implementing CDIO. One of the main responses and answers from the interviewees to questions about CDIO was; "*that's what we're already doing*", "*always have been doing*" or simply "*that's what we do*", even before a CDIO implementation has begun. It's a mind triggering answer often expressed in between other questions, and in the Danish cases almost using the same words. One could suspect an unseen common forum where discussions have already been going on for some time, and where a common verdict has been made. There is recognition of the steps C – D – I – O as an engineering practice used when solving problems; steps that haven't been conceptualized this way beforehand and steps that enable a clarification of how things are done within the engineering profession. This might be the 'aha' experience of CDIO at the beginning of an implementation process and one that also trigger knowledge of what this is all about; staging the process of adopting and developing syllabus and standards as naturally understood and perceived lifecycle views within engineering traditions. The vision or meta-cognition of C-D-I-O as the very steps taken in engineering practices when solving problems is a very strong communicator for CDIO. It heightens the ability to be aware of what is going on and what one is doing.

This lifecycle view giving name to the CDIO program was already seen as a motivation from early on. It was apparently by "*examining what engineers do*", and influences from for instance by Theodore von Kármán's distinction between scientists as making 'discoveries' of the existing world and engineers 'creating' "the world that never was", that the

conceptualization at MIT Aero-Astro came up with the lifecycle system and the phases modern engineers lead or are involved with: Conceive, Design, Implement and Operate [3].

Inherent in the statements given during our interviews, however, also is a revelation of the paradox; why do something we're already doing? One end in answering this question could be that there is nothing new, that it's just "old wine in new bottles" as one teacher put it or the story of a teacher emphasize; placing himself at the end of the table and with an attitude of a top-down initiative being pressed down upon him. Indeed it might in the worst case scenarios of implementing CDIO, be showing complicated ways of communication between management and teaching faculty, neither knowing more fully or appreciating the practices in each other's domains. These could be processes that might be recognized as demotivating and hindering the actual progress when implementing CDIO. On the other hand, and this might indeed also be the ones also joking about new bottles, some finds the phases in the C-D-I-O vision of engineering practices a way both to visualize as well as conceptualize the very same practice: it becomes a common language, as several interviewees expressed, not only in an engineering institution but also between different institutional set-ups and to the professional engineer. It also enables us to make sense talking to each other and distinguishing ourselves from other studies within a larger university situation.

In our interviews and in papers written by the Technical University of Denmark (DTU) the C-D-I-O is at times seen and referred to as a 'philosophy'. Implementing the CDIO at DTU long ago was also substantiated by wanting to make a clear distinction between the undergraduate engineering program with internship and the master-level engineering program without internship. In web publication and interview DTU however also recognize CDIO as a thinking they have practiced before the actual invention of the concept was made:

>"*With some justification, you can probably even argue that a CDIO-thinking has been behind the program right from the engineering academy's inception in 1957, so that perhaps we should rather be looking at the process as a clarification and precision of this mindset than a brand of new, complete different perception of pedagogy*".

IMPLEMENTING CDIO, THE SYLLABUS AND THE 12 STANDARDS
Implementing CDIO at an engineering institution might be seen in light of the four steps of C-D-I-O. Mainly in the Danish example a decision seems to be taken at a Directors level, after taking contact with CDIO, joining a conference or workshop etc., and often by advice from another engineering institution. Actually one institution was invited to join from the CDIO organization directly. Following this a design for implementing CDIO is normally followed, and this process becomes easier in time, as knowledge, templates, papers and experiences are accelerating the adaptation to the local, national institution or university and the various disciplinary conditions. Following a decision at the Directors level, the implementation is designed by a specific CDIO group, coordinating the activities and generally composed of all program directors from the disciplines and pedagogical consultants from within the organization. The main part of the work to be done is carried out at the level of the individual discipline where the program director and professional counselor/coordinator etc. becomes responsible for various tasks. Templates, examples of a syllabus, handbooks, specific institutional ways of fitting CDIO with local practice and tool for changing and developing curricula, teaching and making evaluation procedures is handled by the specific CDIO group, while the making of exact plans and operating CDIO etc. takes place at the discipline level.

Specific initiatives were taken in the implementation process at DTU, where they had several pilot projects before the full scale implementation was put into operation. Later at least two institutions have applied a full scale from day one, implementing CDIO in all disciplines at once allowing different 'tempi' with deadlines for the specific discipline.

The first implementation of CDIO in Denmark happened at DTU. Joining in 2002 they started what later became named a 'pre-pilot' in the mechanical discipline. Later a formal decision on CDIO was made and a first pilot project with CDIO in the chemistry and biotechnology discipline. At the time they felt insecure not knowing exactly how to handle the implementation process. A smaller group was set up around the pilot with people from the discipline, the pedagogical group and the dean, and they began inventing an implementation process. This was a new way of doing things, but no methodology was apparently used, and no external consultancy were hired to help in the process – except the help given from the Swedish CDIO collaborators at seminars.

In this way it becomes clear that implementing in the first years of the CDIO initiative was quite different to the ways possible later when CDIO Syllabus and the 12 standards had been developed. No pilot projects are set up and no huge project management groups established with a clear start and stop of a CDIO project. Instead we find in our interviews smaller organizational groups, not as exhausting in time and energy, and a quicker flow of tools and help to the executing program directors, program coordinators, teachers, part-time teachers etc. The implementation happens in small stages or 'tempi' depending on the situation. One program might start right away as they are already planning a review of the program. Others might be able to work on one or two relationships; others again have gone far in getting the progression right. This form of implementation happens with deadlines and the vision is to collect all new entries into a bigger matrix.

Before the implementation reach the program levels, work is done by a smaller organizational group composed of several interests groups on a management level. This is where we find CDIO is being fitted into the institutional culture, by reflecting how they themselves are doing things. One pedagogical consultant explain, that they already do most of it, like having a student activating teaching, projects, context and a development of competences through a progress in the educations. In this way CDIO tools becomes an excellent systematic way to describe things already done, to check out what is missing, give a vision of improvement and qualification etc., - but also to find out ones unique ways of doing things.

What we heard once again was the recognition like "*but, this is actually what we doing*", "*it brings more clarity, framework of reference*", "*a basis*" and "*foundation*". The CDIO Syllabus and 12 standards bring an added grip of "systematics" and "wholeness" in thinking about the engineering education and the learning outcome for the student. Our interviews showed a focus on the CDIO Syllabus, to some "*the matrix*" or the "*competence profile*". Although the 12 standards were given attention, it wasn't recalled in the same way as working gone into the Syllabus. Actually some reasons for this were simply that 12 was harder to remember and awkward to handle. Some simply put the 12 standards together to make it six or seven instead, to make it less complicated to work with. This is also done in three versions by CDIO on its org. website; either the six themes with the 12 standards in a number sequence in the 'Implementation Kit', the five groups in the 'iKit' or the seven essentials with an asterisk in the '12 CDIO standards'.

Many of the institutions stressed the fact that CDIO gave them a language and sensemaking of what they were doing and also trying to achieve. It is very "engineering like" to present a list of competences and a competence matrix, so all of this was within the management and teachers comfort zone. Sometimes formal education tends to assume that simple recognition of what it teaches is all that is needed, so it attends mainly to this part. In engineering practices experienced teachers are aware and have tacit knowledge that this is not always the case. And with CDIO comes a better conceptual understanding of the difficulties in changing long established approaches in for instance routine practices. Such changes involve unlearning as well as relearning, and to be able to use the knowledge obtained in a range of potentially relevant teaching situations. Until recently the main focus has been on

technical competences; but CDIO has also given a vocabulary to term the personal, interpersonal and processional competences as well. This goes hand-in-hand with many other initiatives like in Denmark with the new 7-point grading scale in 2007, where all institutions should describe their courses with learning outcomes; equivalent with standard 2 "CDIO Syllabus outcomes". The present cooperative work within engineering institutions on improving the syllabus, realizing what's already in the program and what's missing, also brings an added attention to the specific way each institution is making their own interpretations of the syllabus. CDIO is thus seen as a way of making a difference on the institutional level when the fusion with universities is threatening to give a devastating blow to educational engineering practices.

A last point should be made on a practice happening within CDIO. All the people we interviewed was glad to attend the '*CDIO community*', as one named it. This contentment went from being happy in attending meetings, having good collegial conversations, meeting Danes in the same field, meeting an international group and colleagues working in similar programs, - to the more strategic considerations of an improved ability to talk about engineering educations in a bigger university setting, across the variety of institutional setting where engineering educations are taking place, as well. With common information, tools, templates etc. and common platforms and paradigms, CDIO also establishes a forum adding value to educating youngsters with knowledge, skills and attitudes. Motivating, indeed.

CONCLUSION

None of the institutions described much resistance against the CDIO implementation. The interviewees all found that the teachers were either neutral or positive; there were no teachers fighting against the initiative. We think this is based on the fact, that all of the institutions (apart from AAU) have a strong background in an education with a solid base in practice. If e.g. DTU had started with the civil engineering programmes the story might have been very different.

In general the institutions gave these elements as key success factors:
- **Management support**. All institutions stressed the fact that the implementation of CDIO was backed up by the management. It was not one or a small group of enthusiastic teachers but a whole (part of) institutional effort.
- **Evolution, not revolution**. CDIO is seen as a natural way to talk about engineering education; it is compliant with the general view on engineering education in Denmark.
- **Gives a language**. The CDIO syllabus gives a language to talk about personal, inter-personal and professional competences. Teachers typically focus on technical competences (we are all nerds within our field); the syllabus makes it acceptable to talk about the other (often seen as "soft" competences) and gives a vocabulary for this.
- **Has a program view**. CDIO focuses on a whole study-program not just a collection of courses. It helps program responsible to focus on all the learning activities a student encounter at a given point in time. Here the **competence matrix** plays a major role.
- **Support**. There are a lot of support material and helping information available – both in writing and from other Danish institutions.

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Biographical Information

Dr. Jens Bennedsen is Director of study for the bachelor program in computer science, electrical and electronics as well as leader of the CDIO Develeopment Lab at Aarhus University, School of Engineering. After graduating as M. Sc in computer science in 1988, he taught at a bachelors program in computer science for ten years. After two years in industry with the responsibility for implementing a new system development method in a large Danish IT company, he was employed at the department of computer science, Aarhus University and later at the it-vest networking universities. He was responsible for implementing a flexible part-time program in collaboration between four Danish universities. He holds a Ph.D. in computer science. His research area include educational methods, technology and curriculum development methodology, and have published more than 20 articles in leading computer science education conferences and journals.

Mette Birkedahl Christensen, MA Anthropology and Ethnography, and East Asia Studies, University of Aarhus, Denmark. Have been employed in projects with various private business and public organizations, working with IT, organization and anthropology since 1995. Taught various courses at Information Science, University of Aarhus and completed a full Ph.D. program in 2002 before starting work in industry. Worked for three years implementing a new IT system in the public sector. Special research areas include historical theory and anthropology, gender and technology, diversity strategies and recruitment processes, accessing digital resources and MLA collections, STS and Lean processes.

Corresponding author

Jens Bennedsen
Aarhus University, School of Engineering
Finlandsgade 22
DK-8200 Aarhus N
Denmark
jbb@iha.dk