International Quality Up with CDIO Initiative

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Abstract **- There are two challenges that are constantly discussed in higher education: relevance to the working life and quality of education. Answering these challenges means developments in curricula, but also the pedagogical methods used in higher education needs to be evaluated and reconsidered. We identified these challenges in the faculty of Telecommunication and e-Business at the Turku University of Applied Sciences. Therefore we selected an international CDIO initiative to provide us with necessary support in our development efforts. The CDIO initiative is an international educational framework that tries to provide answers to the mentioned challenges. A development project called "International Quality Up with CDIO" was started following the implementation guidelines by CDIO. The goals for the project were based on the fundamental idea of an engineering graduate by CDIO definition: Conceive - design - implement - operate complex value - added engineering systems in a modern team-based engineering environment. In this paper, we present a case study introducing the development project and the early findings of the project. The results show that we still have development tasks to do, but also that our earlier efforts have been successful and right.**

Index Terms - CDIO, Learning, Quality, Relevance to the Working life

INTRODUCTION

A crucial success factor in a worldwide competition is an internationally competitive, high quality educational system. In addition, the role of higher education institutes (HEI's) in regional development is becoming important success factors. It has become evident that structures, contents and implementation methods of higher education degrees have to be renewed in order to meet the challenges set by the changing operational environment. [1] There are two challenges that are constantly discussed in higher education: relevance to the working life and quality of education. Department for education and skills wrote in the Future of Higher Education report for example that as higher education is increased, we must not compromise on quality, and we must make sure that education really matches the needs of the economy [2].

According to our yearly students' feedback study the students of our faculty are not very well aware of their future working life tasks. The average of last two studies for the question "Do you have a clear idea of the working life tasks this degree gives competences for" was 3,14 (1=no idea - 5=very clear idea). Furthermore, if we ignore the answers of the students in the Degree Program in Library and Information Services the average falls to 2,95. However, relevance to working life is emphasized constantly in different reports and publications. The president of European University Association writes for example that according to Lisbon strategy HEI's has to educate competent students for working life [3]. Similarly a Finnish future report states: "It is essential, that in the future competence resources correspond better than today those hands-on tasks offered in working life" [4]. The goals of the degrees at the Universities of Applied Sciences are emphasizing just these working life related competence and development requirements. Furthermore, the development plan of education and research from the Ministry of Education says that the ever faster changes in the operational environment require promoting communication between education, research and working life [5]. In the innovation report of SITRA an action point for the Universities of Applied Sciences is listed: serve primarily the needs of working life. The report continues that HEI's should significantly increase co-operation with companies and the public sector. [6] In the future University and University of Applied Science graduates are expected strong competence in their specific field [7]. Especially the Universities of Applied Sciences should educate competent practice-oriented students rather than produce know-how itself [4].The role of the Universities of Applied Sciences is significant in strengthening the competence base in the field [8]. Development of high professional competence is one of the challenges of the HEI's mentioned in the province plan of Regional Council of Southwest Finland. This competence transfer to the society of southwest Finland should be promoted with all possible means. [9] Integration of different working life competences including communication, project and management skills as well as business skills is essential. However, developing these skills do not need new courses rather development of study methods, learning environments, student guidance and assessment. [7]

On the side of working life relevance it is important to take care of quality assurance. The focus of development actions should clearly be at validating the quality and impressiveness of education as well as internationalization [10]. Quality is emphasized by Regional Council of Southwest Finland as well [9]. Competition and globalization require that the trust to the quality of HEI at national level is not enough rather higher education should be understandable and trusted internationally as well [11]. When focusing on quality the possibility of national and international level comparability should remain and improve [7].

High number of drop-outs and delays in studies indicate that there are problems both in student motivation and in motivating (in our case, the number of drop-outs is 16 percent and only 57 percent of the students graduate within five years after they started their studies). Manual skills, hands-on learning and work placement are essential features in education. However, at the moment these are not provided sufficiently.

1. CDIO as Context*
Adoption of the principle that product and system lifecycle development and deployment are the context for engineering education

2. CDIO Syllabus Outcomes*
Specific, detailed learning outcomes for personal, interpersonal, and product and system building skills, consistent with program goals and validated by program stakeholders

3. Integrated Curriculum*
A curriculum designed with mutually supporting disciplinary subjects, with an explicit plan to integrate personal, interpersonal, and product and system building skills

4. Introduction to Engineering
An introductory course that provides the framework for engineering practice in product and system building, and introduces essential personal and interpersonal skills

5. Design-Build Experiences*
A curriculum that includes two or more design-build experiences, including one at a basic level and one at an advanced level

6. CDIO Workspaces
Workspaces and laboratories that support and encourage hands-on learning of product and system building, disciplinary knowledge, and social learning

7. Integrated Learning Experiences*
Integrated learning experiences that lead to the acquisition of disciplinary knowledge, as well as personal, interpersonal, and product and system building skills

8. Active Learning
Teaching and learning based on active experiential learning methods

9. Enhancement of Faculty CDIO Skills*
Actions that enhance faculty competence in personal, interpersonal, and product and system building skills

10. Enhancement of Faculty Teaching Skills
Actions that enhance faculty competence in providing integrated learning experiences, in using active experiential learning methods, and in assessing student learning

11. CDIO Skills Assessment*
Assessment of student learning in personal, interpersonal, and product and system building skills, as well as in disciplinary knowledge

12. CDIO Program Evaluation
A system that evaluates programs against these 12 standards, and provides feedback to students, faculty, and other stakeholders for the purposes of continuous improvement

*required

FIGURE 1.
CDIO STANDARDS.

Improvements require taking advantage of research and development initiatives as well as the possibilities in service activities, which are natural tasks to the Universities of Applied Sciences being one of the main duties to them. [7] We should be able to utilize more learning environments outside the University [5]. Competences are wasted unless they are targeted to the operational environment. Therefore co-operation between the stakeholders (HEI's, companies and others) is necessary. [4]

All the challenges described above are identified internationally and an international education initiative CDIO has been established [12]. CDIO is an innovative educational framework for engineering whose aims are to develop the content of the education and to improve the relevance of education to the working life. The initiative defines the competences of a engineering graduate following: Conceive-design-implement-operate *c*omplex value-added engineering systems in a modern team-based engineering environment. CDIO is not a dominating initiative rather it assists the HEI's development of education with 12 standards (Figure 1). At the moment many leading engineering educators of HEIs are committed to the initiative (see www.cdio.org).

The vision of Faculty of Telecommunication and e-Business at the Turku University of Applied sciences for 2015 says that we want to be appreciated, innovative and international education, service and research community. Realizing the vision means answering the challenges discussed in this section earlier. We have to develop our operations towards national and international acceptance, our learning results have to be qualitatively measurable and education should be relevant to the working life and its' requirements. The CDIO initiative was selected to provide us necessary support in our development efforts and a development project called "International Quality Up with CDIO" was started. This IQUC-project focuses especially on engineering education, but the CDIO-ideas are applicable in other disciplines as well and we will use this framework throughout our faculty with all degree programs. The main goal of the project is to increase the relevance to the working life by increasing active teaching methods and experiential learning (Standards 7-10). The project offers a natural way to match our R&D- and service initiatives with teaching (Standards 5, 6, 11). In addition, CDIO-initiative provides an international, tested, and qualitative framework to develop our degree programs (Standards 1-4, 9, 12). At the same time possibilities for international comparison becomes better.

This paper presents a case study introducing the IQUC development project and the early findings of the project. The project and its' phases are described in the methods section. In the results section we describe the main development needs in our curricula and analyze our learning environment. In discussion, we reflect the results with CDIO initiative.

METHODS

This research uses a qualitative approach and presents the IQUC development project in the faculty of Telecommunication and e-Business at the Turku University of Applied Sciences. The faculty educates Bachelors of Engineering, Bachelors of Business and Administration and starting 2008 also Masters of Engineering. Altogether there are seven degree programs: Information Technology, Electronics, Information Technology (English program), Information Systems, Business, Library and Information Services and Technology Management (Master program). There are more than 1500 students and we operate in two cities, Turku and Salo, in southwest Finland.

There are five major phases in the IQUC-project. These parts are 1) Introduction to the CDIO initiative, 2) Curricula versus the CDIO initiative, 3) Analysis of the learning environment, 4) Analysis of faculty's present state versus the CDIO initiative, 5) Development actions (See Table 1). The project is planned to be a three-year development process. First year concentrates on analyzing the present state of our education versus CDIO initiative. During the first year, we also start first development actions. Years 2 and 3 focus on development actions.

TABLE 1.
PROJECT PHASES AND METHODS.

Project phase	Methods	Sample
1. Introduction to CDIO initiative	Workshop 1 Workshop 2	Degree Program Managers Whole Personnel
Focus on CDIO Standard 1		
2. Curricula versus CDIO initiative	Workshop 3	Degree Program Managers
Focus on CDIO standards 2-5		
3. Analysis of the learning environment	Web survey	Laboratory managers
Focus on CDIO standards 6-8		
4. Analysis of faculty's present state versus CDIO initiative	Workshop 4 Workshop 5	Degree Program Managers Whole personnel
Focus on CDIO standard 12		
5. Development actions	Workgroup 1	Whole personnel
Focus on CDIO Standards 4-11		

The first phase of the project was done in two separate workshops. Workshop 1 focused on the opinion leaders and the aim was to familiarize ourselves with the CDIO initiative more detailed. Workshop 1 was also the starting point for this whole development project. The project plan was validated there. Workshop 2 was for whole personnel and the aim was to introduce CDIO to the faculty and to get ideas where we can do better.

Workshop 3 focused on curricula related topics. The workshop focused on CDIO standards 3-5.

Phase 3 was a survey of the activities and physical spaces with respect to workshops and laboratories in our degree programs. A similar type of survey has been conducted for example in Stockholm, Sweden [13]. Our survey was carried out as a web questionnaire. There was a group of faculty members that were asked to participate in the survey. For example laboratory managers, IT support personnel and others responsible of the facilities in our learning environment were included. We wanted to gather information about our laboratories, computer classes and group work facilities. The survey was grouped in three parts according to the CDIO standards 6 to 8. First part of the survey concentrated on basic information about the workspaces. Second part of the survey focused on the learning experiences and active learning in these workspaces. The final part of the survey focused on availability and special regulations of the workspaces. The questionnaire had the following questions:

[1] Workspace information

- type,
- campus,
- space in square meters,
- capacity of students,
- personnel related to the workspace.

[2] Learning in the workspace

- level of studies on the workspace (Basic, Advanced, Thesis, R&D),
- main usage,
- topics,
- student usage in hours per week (guided vs. independently),
- equipments

[3] Availability and regulations

- availability for students,
- safety regulations,
- implications of the safety regulations for the availability and usage,
- booking process,
- limitations.

The survey data was analyzed partly quantitatively, but mostly qualitative methods were used. Content analysis was the most used method when analyzing the answers of the open questions.

In workshop 4, we concentrated on analyzing the CDIO standards and our operations. Focus was on analyzing our position in relation to the standards. In workshop 5 the same will be done together with the whole faculty and the main goal is to promote the need to continue the development process.

Phase 5 of the IQUG development project is at the beginning. After the analysis of the earlier parts, we will fully move on to development actions. There are already different development plans that have been agreed. These are for example development plans for Student assessment and for wider combination of teaching and R&D-projects.

RESULTS

The IQUC development project had five phases of which phases 1-3 are finished and phases four and five are unfinished. We introduce primarily results from the finished phases of the project here.

Phase 1 results

Phase one included two successful workshops. Workshop 1 discussed about the CDIO initiative and the acceptance towards the initiative was very positive. We agreed that the development project is important and focuses on the right challenges of higher education.

Workshop 2 was held in March 2007 and the main goal was to commit the faculty for this project and the goals and ideas of CDIO initiative. As a result, a list of development challenges for our faculty was produced:

- Thesis and Work placement process

- Openness to organizations and companies of every kind
- Sensitivity to react for different signals from the working life
- Internal process improvements
- Experiencing the laboratories and comprehension of laboratories
- Human Resource Management
- International compatibility of curricula
- Clarifying and development of assessment
- Embedding real project assignments into current courses
- Different study methods for different students - how to deal with different learners
- Development of personal study guidance
- Teaching and learning for comprehension
- Learning is fun from the start!
- Students' time management.

Phase 2 results

Workshop 3 was held in April 2007 with the focus on analyzing our curricula with the CDIO syllabus. Due to Bologna process the competences have been identified already, but we also recognize that the competences and their descriptions need improvements. The results show for example that the themes of an academic year should be redefined. We agreed that the themes are now somewhat artificial and they do not give the right impression to the students. On the other hand, we agreed that the competence matrixes are at a good level and it is mainly a question of being more exact. In relation to CDIO standard number 4 "Introduction to Engineering" we clearly agreed that there is currently lack of this type of introductory course at the beginning of the studies. However, we discussed that there are some courses or course packages that might be easily modified in a right direction. Anyway, this deficiency was named as one of the next development steps in every degree program. We discussed also the requirements/ideas of the CDIO standard number 5 "Design-Build Experiences" and we noted that our current situation is acceptable. We agreed that our curricula already contain design-build experiences and this was not identified as a major development task. Our curricula are flexible and they offer the possibility to include real-life project assignments in the students' study plans. Nevertheless, we also realized that at the beginning of the studies some course/courses with design-build experiences are needed and therefore the focus should be in developing the introductory course.

Phase 3 results

The web survey was answered by 21 faculty members and 66 different workspaces were described. Most (62 %) of the described workspaces are in our Turku campus and rest (38 %) in our Salo campus. Most of the workspaces are technical laboratories and teamwork workspaces (Table 2). Teamwork workspaces are constantly used for entrepreneurship studies and for courses using problem based learning.

TABLE 2.
WORKSPACES.

Type of workspace	Count
Laboratories	26
Teamwork workspaces	26
Computer Classes	9
Language Lab	2
Entrepreneurship Lab	3
Total	66

The workspaces are actively used from basics studies to research and development projects. Teamwork workspaces are mostly used in basic studies while the usage of technical laboratories is emphasized in advanced studies and research and development projects and assignments.

The capacity of different workspaces varies from 5 to 40 students. Naturally the teamwork workspaces have smaller capacity from 5 to 15 students. Most of the laboratories have a capacity from 20 to 40 students. However, there are also very specific laboratories where capacity is much smaller. A good example is the media laboratory with a capacity of five students. Computer classes have a standard capacity of 25 to 27 study places. Although the number of computers is always not the same rather there are study places for students with their own portable PCs as well.

All our workspaces are equipped with a number of computers and data projectors. Again the type of the workspace is determinant.

There are several different technical laboratories in our University of Applied Sciences (Table 3). Some of the laboratories are common to many degree programs, but there are also very specific laboratories where very specific activities and topics are learned. Laboratories typically consist of several workspaces.

Entrepreneurship is one of our focus areas [14]. Two of the workspaces classified as Entrepreneurship Lab are workspaces for student run cooperatives. The third entrepreneurship lab is student run Microsoft Education Support Center. This center provides support to public organizations for Microsoft's Server Products (see www.escfi.net). Many of the teamwork workplaces are also used in entrepreneurship studies. In the practice enterprise project for example virtual enterprises are operated in multidisciplinary student groups.

Most of the workspaces identified in this survey are open for students without any limitations. These 29 workspaces are mainly teamwork workspaces and computer classes. In 22 workspaces, the access is limited to only students who study the topics in question. In the embedded software laboratory for example only students specialized in embedded software have open access to the workspace. Basically, the same idea is followed in other workspaces classified in this category. Finally, there 15 workspaces were the access is limited even harder. In these workspaces, a normal case is that a supervisor has to be present. Reason for this protocol is purely based on safety regulations. This is the case for example with electronics and physics laboratories. Another reason for limiting the open access is that the equipments are so expensive and sensible that a supervisor or someone more experienced person is needed. There are also certain precautionary measures that have been introduced. Some of the workspaces are equipped with emergency stop buttons that shut down electricity. In addition, there are laboratories where fire blankets and other fire fighting equipments are on hand.

TABLE 3.
TECHNICAL LABORATORIES.

Laboratory	Main activities and topics
Physics	Exercises and experiments of physical phenomena; mechanics, thermology, optics, nuclear physics, electricity and safety at work
Electronics	Exercises and experiments of electronics; electricity measurement technologies, analogy electronics, digital electronics, microcontrollers, programmable logics, audio technology, acoustic measurements, circuit board design and production
Electronics production	Exercises and experiments of electronics production; Soldering, materials in electronics
Embedded software	Exercises and experiments of embedded software
Internet Technology	Exercises and experiments of Internet technology; wireless networks, Voice over IP, network management
Cisco Networking	Exercises and experiments of Cisco Networking Laboratory
Media Technology	Exercises and experiments of media technology; MPEG-2 -encoding, AC -3 Dolby Digital and DTS -encoding, DVD -pre mastering, DVD -Multi -storage, 3D
Radio and Electro Magnetic Compatibility	Exercises and experiments of radio and EMC technology; radio frequency telecommunication, noise resistance, RF-board design, microwave technology
Information systems	Exercises and experiments of information systems; operating systems, server management, www programming, database administration
Telecommunication	Exercises and experiments of telecommunication; Optic telecommunication, data transmission technologies

The respondents estimated both the independent and guided utilization rate of the workspaces. All our computer classes are actively used. The respondents estimate that there are 26 hours of courses per week on average. In addition to normal courses students use these classes to do their exercises, reports and other tasks. In language labs, the estimated utilization rate is around 16 hours per week, but it does not spread equally throughout the year. The respondents were not able to give any estimate for the independent usage. Almost as difficult was to estimate the utilization rate of teamwork workplaces. The courses signed in these workplaces are easily checked, but again the estimation of independent usage is challenging. Anyway, an estimation of 20 hours of independent work per week in teamwork workplaces is given. In laboratories, the estimated guided utilization rate varies from 5 hours to 30 hours per week. The estimation of independent utilization rate varies greatly as well - from 0 to 40 hours per week. In cases of no independent usage for example, we must remember the special safety regulations related to some of the laboratories. In those laboratories where the estimated independent utilization rate is 40 hours per week we have a lot of thesis and R&D-projects that need the laboratories.

Phase 4 results

Phase 4 is not finished at the moment since workshop 5 will be later this year. Workshop 4 was held in April 2007. The main purpose of the workshop was to analyze the whole faculty in relation to CDIO initiative. Basically, this workshop focused on the CDIO Program Evaluation standards (Table 4). Results show how we see our situation in fulfilling the CDIO standards at the moment. We will continue the analysis with whole faculty later on workshop 5.

TABLE 4.
OUR SITUATION VS. CDIO INITIATIVE.

Standard	Analysis
1	Management is committed; Work is still needed to assure all faculty members
2	Competence definitions need improvements
3	Curricula should have clearer themes for study modules
4	Introductory courses are lacking in all degree programs
5	Our project-based learning support this standard; weights now at the end of studies
6	Data has been collected in phase 3; further analysis is needed
7	Our project-based learning support this standard; weights now at the end of studies. In addition, mandatory work placement supports this standard.
8	Problem-based learning and laboratories are good examples of active learning. Active learning should be promoted more.
9	We have a project where teachers have the opportunity to be in the working life three months. Continuing these actions is seen essential.
10	Teacher qualification requires pedagogical studies; Complementary education in active learning methods should be arranged.
11	A separate project to develop student assessment has been started.
12	This workshop was first time we evaluated our operations in relation to CDIO initiative. In addition, internal quality assurance actions have been taken.

DISCUSSION

The beginning of the IQUC-project concentrated on analyzing our education and learning environment. We have systematically prepared our faculty to move to operate according to CDIO initiative. All situations where CDIO initiative has been discussed have been positive. Basically, it seems that we have just been waiting for this kind of an initiative. Now there is an initiative that focuses just on the challenges and problems we have recognized as well. This can be seen for example from the list produced by the faculty in workshop 2. This listing has many similarities to the CDIO initiative. The CDIO initiative offers a framework that our faculty can commit easily.

In workshop 3 we were assured that the beginning of the studies need improvements. There should be something concrete that commits the students for the studies. We recognized that we have had the same idea earlier and there are these concrete introductory courses at the moment. However, we agreed that these courses could be larger and have more focus on the core of the future profession. We decided that for next autumn these current introductory courses are improved in the right direction. Furthermore, we agreed that practical courses should be delivered more evenly during the education. Now practical and concrete courses and experiences locate mostly at the later half of the studies. This was also confirmed with the learning environment survey as the usage of laboratories is focused at the end of studies.

Two of the main duties of the Universities of Applied Sciences are to take responsibility of higher professional education and to do applied research and development. Therefore the list of the main activities and tasks studied in our technical laboratories is not a surprise. Altogether the survey in phase 3 confirmed that our learning environment does not have major deficiencies and development needs. One rationale for such a good situation is that we have new premises in both campuses and the equipment was renewed at the same time we moved there. However, the survey showed that we can utilize our learning environment more efficiently. For example, the utilization rate of the workspaces can be raised but it requires that the use of active learning methods increases. The openness of the workspaces serves the ideas of students actively working with the topics they are studying. The restrictions are also understandable and acceptable and they are not in conflict with the CDIO initiative emphasizing availability of workspaces.

In phase 4, we analyzed for the first time in depth the relation between our education solutions and the CDIO initiative. As the workshop results show our faculty is not starting from zero. We have had different development initiatives constantly that fit well with the CDIO initiative. The practice enterprise project, PBL modules in IT and electronics are good examples of these. They all introduced active learning methods.

The CDIO initiative provides us with an international quality assurance framework. It guides and gives support to our development efforts as a whole. Still, it highlights all the key points of high quality education. It does not focus only on a single topic rather looks the education with a broader view. The CDIO initiative makes you to question your current solutions and ways of doing things. With the short experience with CDIO we are ready to recommend that institutes acquaint themselves with the initiative. Should you not be willing to follow CDIO we believe that becoming acquainted with the initiative is anyway helpful.

REFERENCES

1. ARENE, *The Bologna Process and Finnish Universities of Applied Sciences*. 2007, Helsinki: ARENE.
2. Department for education and skills. *The future of higher education*. 2003 [cited 15.3.2006]; Available from: http://www.dfes.gov.uk/hegateway/uploads/White%20Pape.pdf.
3. Winckler, G. *The Contribution of Universities to the competitiveness of Europe*. 2006 [cited 6.9.2006]; Available from: http://www.eua.be/eua/jsp/en/upload/EUA_Winckler_Handout_160306.1142503397992.pdf.
4. Ruokanen, T., ed. *Roadmap to Finland's Future Success*. 2004, Finnish Business and Policy Forum EVA. 125.
5. Ministry of Education Finland, *Education and Research 2003-2008; Development plan.* Publications of the Ministry of Education, 2003. Finland 2004:8: p. 59.
6. SITRA, *Making Finland a leading country in innovation : Final report of the competitive innovation environment development programme*. 2005. p. 35.
7. Ministry of Education Finland, *Tekniikan alan korkeakoulutuksen ja tutkimuksen kehittäminen.* Opetusministeriön työryhmämuistioita ja selvityksiä, 2005. 2005:19: p. 91.
8. Wikström, K., P. Haikkola, and A. Andresen, *Teknologiateollisuuden tulevaisuus ja liiketoimintamahdollisuudet Varsinais-Suomessa*. 2005, Åbo Akademi & Turku Science Park: Turku.
9. Varsinais-Suomen liitto, *Varsinais-Suomen maakuntasuunnitelma 2025*. 2005, Turku: Varsinais-Suomen liitto.
10. Opetusministeriö, *Korkeakoulujen rakenteellisen kehittämisen periaatteet; Keskustelumuistio 8.3.2006*, in *Opetusministeriön monisteita 2006:2*. 2006.
11. Korkeakoulujen arviointineuvosto, *Korkeakoulujen laadunvarmistusjärjestelmien auditointi - Auditointikäsikirja vuosille 2005-2007*. 2005.
12. CDIO. *The CDIO Initiative*. 2007 [cited 5.1.2007]; Available from: www.cdio.org.
13. Wallin, H. and S. Östlund. *CDIO Workshops and Laboratories Survey for the Vehicle Engineering Program at Royal Institute of Technology, KTH.* 2002 [cited 2006 15.8.]; Available from: http://www.cdio.org/papers/workshops_kth.pdf.
14. Kontio, J. *Adding Studies of Entrepreneurship in Engineering Education*. in *10th IACEE World Conference on Continuing Engineering Education*. 2006. Vienna, Austria.