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Improving Quality Assurance with CDIO Self-Evaluation:
Experiences From a Nordic Project

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ABSTRACT

The main goal of the Nordic project Quality Assurance in Higher Education was to develop and implement a self-evaluation model in the participating Higher Education Institutes (HEIs) to support their quality assurance work and continuous curriculum development. Furthermore, the project aimed at strengthening the cooperation of HEIs in quality assurance (QA) and disseminating good practices of QA. The framework of development is based on the CDIO approach and the CDIO self-evaluation process. The main results are a detailed definition of the self-evaluation process, well-documented self-evaluations of the participating degree programmes, and the identification of the main development areas and actions in each participating degree programme. Furthermore, the project has increased the partners' understanding of other partners and their challenges. Finally, quality assurance has been enhanced in each participating programme and new ideas and support for quality assurance work in other higher education institutes have been produced.

Keywords: *CDIO, Continuous Development, Engineering Education, Higher Education, Nordplus, Programme Development, Quality Assurance, Self-Evaluation*

INTRODUCTION

Quality is a constant concern in higher education. According to the Finnish Higher Education Evaluation Council (2007) improving the quality of higher education institutions increases their national and international competitiveness. Thus, a high quality education system has become a crucial success factor in the world of international competition (ARENE, 2007). As a consequence, the call is now for higher education to be transparent and credible interna-

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tionally (Kettunen, 2008), that is, accountable. The Nordic project Quality Assurance in Higher Education (QA in HEI Project) is intended to provide a model for transparent and credible international accountability.

Accountability in Higher Education

The demand for accountability has intensified for two reasons. First, Higher Education Institutes (HEIs) have been asked to provide evidence of the optimal use of public funds. Second, accountability provides a counterbalance to an increase in institutional autonomy (Kristensen, 2010; Singh, 2010). In the early 1990s the thinking behind quality management in engineering education within Europe began to change, resulting in the development of systematic, award-based total quality management processes. That development was based on pressure from society that demanded proof of programmatic quality as well as added value, despite the fact that the financing of universities was decreasing (Schrey-Niemenmaa, 2011).

At the end of 1990's quality related pressures lead to the development of the Bologna process and Bologna declaration. Since that time the Bologna declaration has influenced European higher education significantly. One of the action points in the declaration is the promotion of European co-operation in quality assurance (European Commission, 1999). The Bologna declaration and related Lisbon strategy provide the main guidelines for increasing the competitiveness of European higher education. They call for improvements in the quality of education. In particular, the Lisbon strategy calls on Higher Education Institutes (HEIs) to provide education that conforms to the competence requirements of working life (European Union, 2004). HEI must not compromise on quality, and they must make sure that education really matches the needs of the economy (Department for Education and Skills, 2003).

The Finnish Ministry of Education also stresses the quality of education, stating that the quality of teaching and graduates is a prerequisite for the efficiency and productivity of education (Ministry of Education Finland, 2007). Furthermore, it is evident that the 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 (ARENE, 2007). An example of this kind of renewed thinking is that of a Finnish Collaboration Group. This group developed a set of criteria for a *good engineering education campus* and provided specific proposals for action to meet the criteria (Korhonen-Yrjänheikki, 2011).

The European Association for Quality Assurance in Higher Education (ENQA) is one example of how the Bologna declaration has been implemented. Another example is the European Accredited Engineering (EUR-ACE, http://www.enaee.eu) project that establishes a European system for the accreditation of engineering educational programmes (Augusti, 2007).

Competition and globalisation means that mere trust in the quality of HEIs at the national level is not enough. They require that a HEI's quality be made visible through the use of evaluation systems that are internationally respected (Finnish Higher Education Evaluation Council, 2007). That is, when focusing on quality, national and international comparability should be sought (Ministry of Education Finland, 2005). In addition, the need for the trans-national *accreditation* of education is becoming increasingly important due to increased physical and virtual mobility, the growth of new degrees programmes, and the increase in new educational institutes (Augusti, 2007). The Nordic project Quality Assurance in Higher Education is an attempt to develop closer co-operation in international quality assurance.

Quality Assurance

The Finnish Higher Evaluation Council defines quality assurance as all the procedures, processes and systems used by a HEI to manage and improve the quality of its education and related activities (Finnish Higher Education Evaluation Council, 2008). On a European level,

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quality assurance policy is coordinated by the European Association for Quality Assurance in Higher Education (ENQA). The ENQA has produced a list of European standards for quality assurance (European Association for Quality Assurance in Higher Education, 2007). These standards have three parts: internal standards and guidelines, external standards and guidelines, and standards for external quality assurance agencies. Furthermore, in each European country there are a number of organisations and agencies that are responsible for the external auditing of HEIs.

The efficacy of the external quality assurance is highly dependent on an institution's internal quality system and quality culture (Kristensen, 2010). Therefore, self-evaluation is an important part of any quality system (European Association for Quality Assurance in Higher Education, 2008). In a self-evaluation, an institute systematically reviews and reflects on the quality of instructional and related educational services and on the outcomes they produce (OECD, 2011). For example in Finland, the higher education institutes are responsible for their own quality assurance which is then evaluated by the Finnish Higher Education Evaluation Council (http://www.kka.fi/?l=en&s=1). The Nordic project Quality Assurance in Higher Education (QA in HEI Project) builds on the quality systems and quality cultures of the participating HEIs.

How does CDIO Fit into Quality Assurance?

The overall idea of the Conceive-Design-Implement-Operate (CDIO) approach is to support engineering education development and educate students who are able to (Crawley et al., 2007):

- master a deeper working knowledge of technical fundamentals
- lead in the creation and operation of new products, processes and systems
- understand the importance and strategic impact of research and technical development on society.

Important tools in this task are the 12 CDIO Standards (CDIO, 2011) and the CDIO Syllabus (Crawley et al., 2011). The CDIO Standards act as guiding principles for the design and development of a degree programme. Focusing on development in the areas defined by the standards lead to improved results, that is, students learning more and having a better experience at their HEIs. The standards address issues related to what to teach and how to teach, as well as those related to staff development and workspaces. In addition, the standards address the assessment of student learning and the evaluation of the quality of programmes relative to their compliance with the CDIO Standards. This is the fundamental starting point of the Nordic project Quality Assurance in Higher Education Institutes (QA in HEI Project) described in this article.

QA IN HEI PROJECT

The QA in HEI project was funded by Nordplus (2011). The project started in October 2009 and continued until the end of October 2011. The project had four partners: Turku University of Applied Sciences (TUAS) (Finland) was the coordinator, and the Swedish Royal Institute of Technology (KTH), the Technical University of Denmark (DTU), and Helsinki Metropolia University of Applied Sciences (Metropolia) (Finland) were the other partners. The project followed a typical quality assurance structure where self-evaluations were designed in connection with an external evaluation activity (OECD, 2011).

The main goal of the QA in HEI project was to develop and implement a self-evaluation model in the participating HEIs, in order to support their engineering education related quality assurance and continuous curriculum development. The project was intended to refine the self-evaluation process in the HEIs and develop

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new tools to support the internal process of quality assurance. Quality assurance models were established, implemented and further developed in the participating degree programmes. Using these newly developed methods, the quality of education was monitored and actively improved in the participating HEIs.

Furthermore, the project aimed at developing cross-evaluation methods for international use. The main purpose of this international cross-evaluation emphasis was to provide the HEIs with new methods and tools for international quality assurance work in close co-operation with other HEIs. The result of the cross-evaluation between HEIs was the enhancement of both their quality assurance efforts and the quality of education provided.

Another objective of the QA in HEI project was to construct a framework for quality assurance that promotes the international comparability of educational quality. Thus, the project aimed at creating a cyclical model for continuous quality assurance that would foster an active development culture. In this cyclical model, the quality of education was reviewed by using self-evaluation and cross-evaluation methods. Based on the evaluation results, development actions were defined, planned, and implemented in order to promote educational quality.

In addition, the project was intended to strengthen the co-operation of the participation Nordic HEIs and to disseminate the best practices of quality assurance methods and educational solutions to other HEIs. The international cross-evaluation model, by definition, promotes cooperation and the comparability of educational quality on both the Nordic and international levels.

The project was divided into two phases that had different focuses. The first phase focused on the self-evaluation and it contained the following steps:

1. Definition of the self-evaluation process
2. Conducting the self-evaluation in the selected degree programmes
3. Analysing the results of the self-evaluation and defining development activities
4. Assessment of the self-evaluation criteria and process based on the experiences gained

The second phase focused on the cross-evaluation, but this article only focuses on describing the first phase of the project.

Each HEI defined a degree programme that would pilot the self-evaluation model and participate in the cross-evaluations in the second project period. Each partner institution had a core group of persons working on the project that typically included the local CDIO leader, a quality assurance expert and degree programme manager/leader. In addition, a working group of local experts followed the self-evaluation model and produced specified documentation. Finally, the QA in HEI Project had a steering group consisting of the local CDIO leaders.

DEVELOPED MODEL AND GUIDELINES

At the beginning of the project, the three main steps of the self-evaluation process were defined:

1. Create a programme description
2. Perform the self-evaluation
3. Define possible development actions.

The programme description contained the following topics:

- Introduction
- Description of the programme goals and structure
- Description of the curriculum and courses
- Description of the selected themes
  - Introduction to higher education study and to engineering
  - Training of engineering competences
  - Thesis work
  - Engineering workspaces
- Student – work life connection
- Description of the continuous development process

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The description should be specific enough to allow the programme to perform an evaluation. We agreed to base the evaluation mainly on existing documentation in order to minimise the production of artefacts that would only serve the purpose of this evaluation. The assumption was that if the evaluation inspires improvements in the *real* documents, it may also contribute more directly to developing the programme. The evaluation guidelines included several supporting questions to help construct the programme description.

The self-evaluation was based on the programme description. It consisted of the actual ratings of the programme in relation to the CDIO Standards and resulting recommendations for improvement. The CDIO Standards were grouped as follows to clarify the structure of the self-evaluations:

- Criterion A. Programme goals and design
  - Standard 1 – The Context
  - Standard 2 – Learning Outcomes
  - Standard 3 – Integrated Curriculum
- Criterion B. Course goals and design
  - Standard 4 – Introduction to Engineering
  - Standard 7 – Integrated Learning Experiences
  - Standard 8 – Active Learning
  - Standard 11 –Learning Assessment
- Criterion C. Selected themes
  - Standard 5 – Design-Implementation Experiences
  - Standard 6 – Engineering Workspaces
- Criterion D. Continuous development
  - Standard 9 – Enhancement of Faculty Skills Competence
  - Standard 10 – Enhancement of Faculty Teaching Competence
  - Standard 11 – Learning Assessment
  - Standard 12 – Programme Evaluation

The products of the self-evaluation were the self-evaluation report, a description of the three best practices identified by the programme, and a description of the local implementation of the self-evaluation process. Possible development actions were defined, documented and scheduled based on the self-evaluation and were summarised in an action plan.

SELF-EVALUATION PROCESSES AND RESULTS

All project partners were dedicated to achieving the project goals. The follow presents the results of the self-evaluation. In addition, development activities suggested are discussed by the principal participants in the project.

Case: Turku University of Applied Sciences (TUAS) (Finland)

During the past few years the Turku University of Applied Sciences (TUAS) degree programme in Information Technology has participated in several different evaluation processes. The programme participated in an internal TUAS cross-evaluation process in 2007 (Hyvönen et al., 2007) where different phases of the programme planning, implementation, evaluation and improvement processes were studied. One of the recommendations was that there should be greater collaboration with other HEIs.

In addition, the programme was a candidate for a national centre of excellence in education award for 2010-2012 (Hiltunen, 2009), and the application process included an extensive self-evaluation process. Moreover, The Finnish Higher Education Evaluation Council audited the quality assurance system of TUAS in autumn 2009, and the programme participated actively in the collection of audit data (Hintsanen et al., 2010).

All these evaluation processes involved the faculty and programme management, teachers and students. Thus, this CDIO self-evaluation process was based mainly on the existing materials and experiences gathered during the previous exercises, complemented with CDIO specific parts, and a student survey conducted by a student representative in the QA in HEI Project.

The QA in HEI Project self-evaluation process provided an opportunity to reflect on the

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processes and operations of the programme from different perspectives. It especially focused on the topics emphasised by the CDIO approach. Topics that were present in the continuous development process of the programme were also discussed during this self-evaluation. For example, defining and improving the programme and course level learning objectives has been one of the main areas identified for improvement during the past two years. Currently, this process focuses on defining and improving assessment criteria – there is still much to do in that field.

In addition to these ongoing development actions, four specific improvement items were identified during this self-evaluation:

- CDIO capstone project: The current curriculum is flexible and encourages students to participate in different types of projects especially during the second half of their studies. However, these projects are not a mandatory part of the curriculum, and furthermore the projects are often started on an ad-hoc basis. Thus, the curriculum should be studied and a CDIO capstone project should be included within it in a more integral way than before.
- International elements: In addition to this programme, our faculty also has a fully international degree programme in Information Technology. These two programmes have a long tradition of cooperation (shared facilities, joint courses and teachers, etc.). However, the cooperation – especially from the students' perspective – is focused on the latter part of the programmes. Hence, more cooperation should be conducted at the beginning of the programmes. This could also improve the internationalisation and networking skills of the Finnish students and, moreover, make it easier for foreign degree students to integrate into the Finnish student community.
- Practical training: The curriculum contains mandatory practical training worth 30 ECTS credits. During the evaluation process it was identified that the learning objectives and the assessment of the practical training course especially need to be updated and improved.
- CDIO awareness: For some years now, the programme has been developed according to the goals set by the CDIO Standards. However, awareness about CDIO and its elements is not at a very high level, especially among students. Thus, actions to improve this will be planned and implemented.

Case: Swedish Royal Institute of Technology (KTH)

In the Royal Institute of Technology (KTH) the Chemical Engineering programme from the School of Chemical Science and Engineering participated in the QA in HEI Project. The programme is not a fully-fledged CDIO programme yet, but it is inspired by the CDIO approach and has informally adopted many CDIO ideas over the years. So far, the main focus of the programme has been on the integration of communication skills. Last year, KTH decided to proceed and implement CDIO in all programmes, and now more coherent plans are being formed for each programme, including this one.

The self-evaluation process of the three-year Bachelor programme in Chemical Engineering focused on creating a programme description. The actual CDIO evaluation and rating have not been created yet. The programme description will be used first in teacher meetings and, second, for the actual evaluation and rating. The self-evaluation process itself was very time-consuming work. This should be discussed and possible changes to the guidelines should be considered.

The programme description has been well made and there should be possibilities for exploiting it. For example, based on the self-evaluation, the Chemical Engineering programme identified several strengths and weaknesses. The major findings regarding potential development actions are the following:

- Programme organisation–programme management team including student representa-

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tives: The student representatives for the Chemical Engineering programme should be included in the programme's management. So far the role of the representatives has been slightly unclear.
- New funding systems: Should they reflect quality?
- International aspects: The programme is intended to prepare students for advanced studies, thus the students should be required to learn adequate technical English.

Case: Technical University of Denmark (DTU)

The self-evaluation process of the Bachelor of Engineering (BEeng) programme in Chemical and Biochemical Engineering at the Technical University of Denmark (DTU) was conducted somewhat differently from the other programmes involved in this project. After having been introduced to the project and its aims by the local Nordplus Project Coordinator, the Director of Studies formed an evaluation group consisting of two teachers, two students and himself. This group collected data for the self-evaluation report by looking through the official documents (syllabus, etc.) and by talking to fellow teachers and students in order to include their opinions and experiences. They then collaborated on writing the self-evaluation report and subsequently discussed the report with the department's board.

In order to take the self-evaluation a step further, the report and the findings were discussed during an evaluation meeting at DTU with the participation of all directors of studies and the dean of studies. The purpose of this meeting was to share the findings with the director of studies and other colleagues, in order to identify and discuss action for improvements in the Chemical and Biochemical Engineering programme as well as to study programmes at DTU in general.

Since many programmes face the same challenges, this meeting seemed valuable to all the participants and some more general conclusions were drawn. The most important of these was the creation of so-called helicopter documents showing the ideas behind the study programme and describing the structure and progression of the programme. In other words, it is a description of all the details that are not covered in the official programme documents. The content of this document should be made clear to all teachers in the programme and it should be revised regularly in order to reflect the actual situation at any given time.

In the light of the various discussions of the self-evaluation report, the director of studies and the local project coordinator drafted a document containing several development areas. So far only a few of these areas have been addressed but more will be addressed in relation to and in the wake of the ongoing peer evaluation process within KTH, which has not yet been carried out.

The self-evaluation of the BEeng in Chemical and Biochemical Engineering identified several strengths and weaknesses concerning the programme. The major findings regarding potential development actions are the following:

- Learning assessment: It is a challenge to assess CDIO skills in the evaluation. This is a challenge for all programmes at DTU and probably all CDIO programmes. Ways of improving the assessment of CDIO skills will be considered in the future.
- Validation of learning outcomes by stakeholders, particularly students and industry: This form of validation is conducted to a limited extent at the moment. Ways of improving this in the future should be considered, for example, by having more systematic discussions with the advisory boards and by using scheduled graduate surveys.
- Alignment of learning objectives at course level and the competence profile for the programme: The programme has been developed according to the goals set by the CDIO Standards for some years now. However, the competence profile must be more properly aligned with the learning objectives at the course level. There are a few

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qualifications in CDIO Syllabus category 4 (conceiving, designing, implementing, and operating systems in the enterprise and societal context) that have not yet been properly addressed in the study programme. The possibilities for incorporating these qualifications into the study programme in the future should be discussed.

- CDIO awareness: There is still a high degree of privacy about teaching and evaluation methods. It seems that there is great potential for the improvement of communication among teachers. More systematic meetings in teacher teams are a possibility to address this concern. A *helicopter document* that shows the ideas behind the study programme and describes the structure and progression of the programme should be produced. The content of this document must be clear to all teachers in the study programme and should be revised every year in order to be constantly updated. In particular, in the BEng programme in Chemical and Biochemical Engineering at DTU the students work in the phases C-D-I. The only possible contact with the O-phase is during the engineering training placement within the industry. It is difficult to work with the *Operate* phase in chemistry. Possibilities for developing this phase should be taken into consideration.

Case: Helsinki Metropolia University of Applied Sciences (Metropolia)

Helsinki Metropolia University of Applied Sciences (Metropolia) systematically evaluates the implementation of its instructional strategy, the operations of the institution, and the level at which objectives are achieve. Instructional strategy and institutional operations are improved based on the results of the evaluation and feedback systems so that Metropolia provides enhanced services to meet the needs of our customers, that is, students and other stakeholders like industry, professional organisations and society. The strategy and operations of the institution are developed in a co-operative way with staff, students and stakeholders.

The implementation of the major objectives of Metropolia, the development of its operations, and the enhancement of quality and competiveness are based on continuous improvements that are made according to the principles of Plan – Do - Check - Act (PDCA).

The *quality assurance* system at Metropolia is based on strategic leadership and management. It includes precisely described supportive core processes and information and feedback systems, and operational guidelines and organisational responsibilities related to them.

The implementation phase of CDIO approach was carried out in 2009, just one year after Metropolia became a collaborator in CDIO. Therefore, the results are not reliable due to the diverse viewpoints on CDIO, although the evaluation was a good beginning as it increased the awareness of CDIO as a concept. In 2010, a self-evaluation process was carried out that produced strategic objectives for all of Metropolia. The key findings of the self-evaluation – in SWOT-format – are shown in Figure 1.

In summary, development areas were identified in relation to four major challenges:

1. How can we supervise and manage a great number of innovation projects that run simultaneously?
2. How can we increase the knowledge of students so that they can develop an international career in engineering?
3. How can we better manage the work placement arrangements to improve connections between industry and Metropolia?
4. How can we integrate teaching activities, increase CDIO awareness, and carry out the implementation of the CDIO approach?

DISCUSSION

The Nordic project Quality Assurance in Higher Education (QA in HE satisfactorily met all the planned objectives:

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Figure 1. Metropolia SWOT-format

- Guidelines and evaluation criteria for the self-evaluation process have been created.
- HEIs have documented their participation in the degree programme in detail.
- Each participating programme has conducted a self-evaluation.
- Each programme has identified the main development actions based on the self-evaluation.
- The understanding of other partners and their challenges has increased.
- Quality assurance has been developed in each participating programme.

The guidelines and evaluation criteria for the self-evaluation process were successfully used. The developed self-evaluation model functioned, but at the same time it was a very time consuming process. However, the process was also rewarding in the sense that those who worked on the report gained a very good overview of the programme. Furthermore it is valuable to be *forced* to look closer at one's own programme. The self-evaluation documentations were very thorough and they described the programmes well. In this sense, it seems that the guidelines and criteria provide useful help for the self-evaluation. Finally, the self-evaluation helped the programmes to identify possible development areas, creating material and evidence for programme development. Interestingly, the development areas partly overlapped and showed a common need for development, which could promote future co-operation.

The self-evaluation rated the performance according to CDIO Standards. In this project we still used the older set of standards where there were no individual rubrics for each one. The scoring used provided a rewarding and easy way to show progress in development, but it does not guarantee comparability with other programmes. The scoring is still a very subjective process. Therefore it is important that reasonable rationales for the scores are attached, otherwise it is difficult to demonstrate and analyse progress. The new CDIO Standards v2 with customized rubrics is a step forward (CDIO, 2010).

The co-operation between project partners has been successful and has become closer since the beginning of the project. Every partner HEI

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was committed to the project objectives and timetable. Regular meetings between project partners have been very fruitful and provided plenty of new development ideas. The project has initiated close cooperation between the Nordic partners and we intend to continue working together in the area of quality assurance in education. All experience gained from the self-evaluation work will also be utilised in the future when evaluating degree programmes in individual HEIs.

CONCLUSION

The self-evaluation model created in this project is a good tool for improving quality assurance in higher education. The model provides easy-to-follow guidelines and criteria for self-evaluation. However, the model also needs some modification, such as determining the exact content of the self-evaluation report to be discussed at the end of the whole project.

The QA in HEI Project focused on engineering education, and thus the participating HEIs and degree programmes represented the engineering field. Although the educational challenges nowadays concern higher education on a general level, engineering education in particular is being challenged to develop new methods of quality assurance work in order to produce experts that meet the growing demands of working life. However, the project results can be further developed and adapted to other educational fields by refining the methods and tools developed.

The QA in HEI Project encouraged the programmes to conduct self-evaluations and to define the development areas. Hopefully, the project also introduced a quality assurance spirit into the programmes that will ensure that self-evaluation becomes a regular method in the quality assurance of the programmes.

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