Queen's University Centre for Educational Development
Case Study

Title	The CDIO Initiative: International Collaboration in the Development of Engineering Education

Context
Internationalisation
School of Mechanical & Aerospace Engineering

Activity

The School of Mechanical and Aerospace Engineering is playing a leading role in an international initiative to reform engineering education. The initiative originated at the Massachusetts Institution of Technology (MIT) in the late 1990s, when staff began to question the validity of the traditional engineering curriculum. Specifically it was felt that the traditional curriculum adequately covered the science and maths that underpin engineering, but failed to address the areas that distinguish an engineer from a scientist. It was argued that, unlike science, engineering is a creative discipline. More specifically, "engineers are primarily involved in the conception, design, implementation and operation of value-added products and systems" (where "implementation" refers to the conversion of designs into physical entities). In order to highlight the unique aspects of engineering, the MIT staff decided to adopt the acronym formed by "conceive, design, implement and operate", and launched what they called the CDIO Initiative [1]. The intention was to emphasize that understanding the relevant science and maths is insufficient, and that engineering students need to know how to apply science and maths to the task of creating products and systems. In addition they need to acquire the generic knowledge and skills associated with conceiving, designing, implementing and operating products and systems, along with the personal and interpersonal skills needed to pursue careers as professional engineers.

By 1999, the CDIO Initiative had become a collaborative venture involving MIT and the Swedish universities; Chalmers, Linköping and KTH. In 2003 the four collaborators decided that they wanted other universities to participate, and Chalmers suggested Queen's. They chose the University because a student exchange programme was in operation between Chalmers and what was then the School of Mechanical and Manufacturing Engineering. Following visits to QUB by staff from Chalmers and MIT, the School was invited to apply to become the fifth member of the CDIO Initiative. An application was submitted with the full support of the School's staff, mainly because the School held the same views about the need to reform engineering

education (but also because MIT is the leading engineering university in the world).

Since the School became the fifth collaborator in the CDIO Initiative, the number of participating universities has grown rapidly. It now stands at 29, and is likely to continue rising at a rate of 8 to 10 universities per year. The current collaborators included universities from Canada, the USA, South Africa, Singapore, China, Jordan, Australia, New Zealand, Sweden, Finland, Germany, Belgium, Denmark, Portugal, Italy and the UK. Globally the CDIO Initiative is by far the largest collaborative programme in engineering education.

International meetings of the collaborators are held twice a year at a participating university. (Queen's hosted a meeting in 2004.) Starting in 2005, an international conference has been linked to one of the biannual meetings. Papers are not restricted to the collaborating universities and the conference has grown in size and stature year by year. Guest speakers have included senior executives from multi-national companies and international figures in education research.

In 2004 a CDIO Council was formed to direct the development of the CDIO Initiative. Members of the Council were drawn from representatives of the first eight universities to join, and two members are from QUB. Staff from the School also chair two of the five committees responsible for developing the "CDIO approach", and the School has been closely involved in the organization of the annual conferences, CDIO workshops and other events.

As a collaborator in the CDIO Initiative, the School is engaged in three main activities:

- The development of the CDIO approach, which has become a comprehensive methodology for designing and redesigning engineering degree programmes.

- The implementation of the CDIO approach in the School's undergraduate programmes.

- Dissemination of information about the CDIO approach and its implementation.

Development of the CDIO Approach

Sessions are scheduled at each international meeting for work on the development of the CDIO approach. Currently those present join one of five "theme groups", that focus on curriculum design, teaching and learning, assessment, learning spaces and dissemination. Ideally this

means that five representatives from each of the collaborating universities should attend each international meeting. In practice some universities cannot fund this level of participation, but most send at least two or three staff.

The theme groups report the progress they have made at the end of each meeting, and also schedule a series of telephone conferences for the period until the next meeting is due. Contributions are also made to the development of the CDIO approach by staff from the individual universities involved in the initiative. However, it is becoming more common for staff from two or more universities to work together on an aspect of the CDIO approach that they share an interest in. In both cases the work undertaken is generally reported at a CDIO conference. Having said that, the most challenging example of a collaborative publication was a review of the status of the CDIO approach which was written by 15 authors (including one from QUB) and published recently as a book [2].

Although the development of the CDIO approach is on-going, a comprehensive methodology for designing and redesigning engineering degree programmes now exists. The initial ideas put forward by staff at MIT were used as a basis for a CDIO Syllabus and a set of CDIO Standards. The Syllabus defines in fine detail the knowledge and skills that an engineering graduate should possess. The Standards cover the design and delivery of the curriculum, including the need to incorporate active and interactive learning, a variety of conceive, design, implement and operate experiences and significant provision for developing personal, interpersonal and professional skills. The CDIO methodology defines the processes involved in transforming the CDIO Syllabus into learning outcomes for individual modules and developing a curriculum that meets the CDIO Standards.

Implementation of the CDIO Approach in the School's Undergraduate Programmes.

Traditionally the School has offered degrees in Mechanical and Manufacturing Engineering at BEng and MEng level. Amalgamation with the School of Aeronautical Engineering added BEng and MEng degrees in Aerospace Engineering, and in 2004 the School introduced new degree programmes in Product Design and Development. Since joining the CDIO Initiative, the School's intention has been to implement the CDIO approach in all of its degree programmes.

Introducing the Product Design and Development degrees provided the School with an opportunity to design new programmes that embodied the CDIO approach from the start. This has resulted in distinctive programmes that the School believes provide students with

a coherent curriculum, engage them more fully in the learning process and better prepare them for professional careers. Redesigning existing programmes has been a more challenging task that has required phased implementation over a number of years. However, significant progress has been made, particularly with the introduction of conceive, design, implement and operate projects and the addition of new introductory modules that develop essential skills and provide initial hands-on engineering experiences.

Dissemination of Information about the CDIO Approach

The CDIO collaborators believe that the reform of engineering education is a global requirement, and that the methodology which has been developed is applicable worldwide. The rapid growth in membership is evidence that dissatisfaction with the status quo is not confined to any one country or continent. Dissemination of information on, and an understanding of, the CDIO approach have therefore had a high priority from the time the four founding members decided to involve other universities.

One day of each international CDIO meeting is devoted to workshops designed to introduce the CDIO approach to universities in the host country. Staff from the School invariably contribute to the organization and delivery of the workshops. The School has also taken responsibility for dissemination within Ireland and the UK. This has involved setting up a regional CDIO group, with assistance from colleagues at the University of Liverpool, who are also collaborators. Regular meetings of the UK and Ireland CDIO group have been organized, and workshops have been held in a variety of universities. Academics from over 20 universities have attended the meetings and workshops to date, including staff from Cambridge, Imperial, Manchester, Nottingham, Bristol, Leeds, Strathclyde, Trinity and Limerick.

Evaluation/Reflection/Outcomes
Benefits to the School

The primary reason for joining the CDIO Initiative was the School's desire to improve the education of its undergraduates, and it is believed that this desire is being fulfilled. Having played a leading role in the growth of the CDIO Initiative from small beginnings to an international organization involving 29 universities, it is reasonable to claim that the standing of the School, and that of the University, have also benefited. However, many other benefits have accrued from working with academics from countries as diverse as South Africa, China, Jordan, Singapore and the USA. While their views on the problems to be addressed in engineering education are remarkably similar, their diverse opinions on appropriate solutions provide

significant "food for thought" for the other collaborators.

Ultimately the CDIO collaborators agree on solutions, and a number of universities attempt to make similar changes in their programmes. Each university then reports back at an international meeting or annual conference, and there are clearly mutual benefits from this sharing of experience. In some cases universities gather detailed evidence on the impact of the change they have made, and positive results reassure those who are contemplating a similar change. In fact over the years a considerable volume of evidence and results has been generated and it was recently agreed by the CDIO Council that this should be reviewed and catalogued.

It has often been observed within the CDIO Initiative that academics often form research links with other universities, and regularly meet with researchers in the same field at national and international conferences. However, academics rarely make contact with those who teach the same discipline in other universities (apart from limited contact with external examiners). A fundamental benefit of participation in the CDIO Initiative has therefore been the opportunities it provides to "compare notes" with fellow academics with the same teaching interests. In addition it has been highly beneficial to see at first hand the work spaces and facilities available to students studying the same discipline in different universities around the world.

Challenges

Participation in the CDIO Initiative has created challenges in terms of the demand it has placed on the School's financial and human resources. Staff attendance at international meetings has required significant funding, and there have been further costs associated with running the UK and Ireland CDIO group. The demand placed on the School's human resources has arisen mainly from the time and effort needed to implement the CDIO approach in the School's degree programmes. The phasing of implementation over a period of years has been essential, in order to minimize the impact on the ability of staff to fulfil their other commitments. Inevitably there has also been some resistance to change, but this has been offset by the fact that over half the staff in the School have attended at least one international meeting of the CDIO Initiative.

An announcement by DEL that funding would be available to set up a number of local Centres for Excellence in Teaching and Learning (CETLs), provided an opportunity to acquire additional resources. A proposal seeking support for the School's involvement in the CDIO Initiative ultimately led to the establishment of a Centre for Excellence in Active and Interactive Learning (CEAIL), for which the School shares

responsibility with the School of Biosciences at Queen's. As a result, assistance with the cost of attending international meetings became available. In addition the School was able to appoint a Teaching Fellow for five years to undertake work related to the CDIO Initiative.

In 2005 a proposal was submitted to the UK Centre for Materials Education (UKCME), which is funded by the Higher Education Academy (HEA). UKCME had launched a Supported Change Programme, with the aim of supporting schools that were planning to introduce changes that would enhance their degree programmes. The School's proposal was successful, resulting in the award of a modest grant but, more importantly, access to assistance from two "facilitators" from UKCME. The role of the latter has been to engage with the staff involved in a proposed change in a programme in order to ensure that they were fully supportive, and that their views were fully represented in the goals that were to be achieved. The assistance of the UKCME staff was particularly helpful in the case of the new introductory modules that are now embedded in all of the School's programmes, each of which required contributions from a number of academic staff.

The CDIO Initiative also faces challenges, stemming mainly from the fact that it has become a "victim of its own success". An international meeting may now be attended by more than 100 representatives of the participating universities. As a result the theme groups have become unwieldy, and the Council is considering alternative arrangements for organizing the development of the CDIO approach. The need for some form of central administration has also become apparent, although this has been resisted to date. However these are minor drawbacks compared to the benefits of an expanding organisation in terms of its growing international influence, and the increasing diversity of its membership.

Implications for Other Disciplines

There has been some discussion within the CDIO Initiative as to the applicability of its approach to other disciplines apart from engineering. The basic principle behind the CDIO approach is that the first step in designing or redesigning a degree programme should be to define clearly the professional roles and responsibilities that will be assumed by graduates. This is obviously not an original principle, but the CDIO collaborators proceeded to consult widely in order to specify in fine detail the knowledge and skills that graduates would need as professional engineers. The outcome was the comprehensive CDIO Syllabus. Programme learning outcomes in effect weight the relative importance of the topics in a syllabus, usually by adding appropriate cognitive verbs. In the CDIO methodology the relative importance of

different topics is determined by surveying the programme's stakeholders, the most important of whom are the programme's alumni. This is carried out on a programme by programme basis, and hence the School sent questionnaires to 800 alumni of its Mechanical Engineering programme. The CDIO Standards are also based in part on the graduate's professional roles and responsibilities. In addition, they incorporate what the collaborators regard as best practice in teaching and learning, curriculum design and programme management. From this outline description of the CDIO approach it is apparent that a similar approach could be developed in other disciplines, but with the qualification that it may only be viable in the case of vocational disciplines. The obvious advantage is that it can be assumed that graduates from a vocational programme will take on similar, if not the same, professional roles and responsibilities.

The lack of communication between academics teaching the same subjects in different universities has been noted. However similar groups to the CDIO collaborators could be envisaged in other disciplines (and some may already exist). Recalling that the School was contacted by Chalmers because a student exchange programme was in place, it is possible that existing links through ERASMUS and other programmes could be used to initiate collaboration between teaching staff. The School has in fact set up exchange programmes with a variety of European universities, and the contacts created have, in a number of instances, led to joint student project work and collaborative research.

While funding for educational development and international co-operation has been cited as a challenge, the School has been able to acquire assistance from a number of sources. Although the funding available for educational initiatives cannot compare with that available for research, the situation is (hopefully) changing. Internal funding within universities is becoming more generous, as are the funds available from the Subject Centres of the HEA. The £315 million invested by HEFCE in the English CETLs represented a major increase compared to any previous example of government support. Hence the indications are that educational initiatives will have greater access to funds, and it is likely that collaborative projects will be looked upon more favourably. In the case of the CDIO Initiative, it may be worth noting that international bodies such as UNESCO have recently been in contact with the CDIO Council. This may signal a realization that higher education has common problems around the world, and that international solutions may be a more efficient way of addressing them. If this is the case, then the CDIO Initiative may turn out to be a trailblazer for educational initiatives in other disciplines by gaining the financial support of international organizations.

References

[1] The CDIO Initiative website is www.cdio.org. (The website will shortly be updated and redesigned, but is currently rather disorganized.)

[2] Crawley, E., Malmqvist, J., Ostlund, S. and Brodeur, D. (Eds.), "Rethinking Engineering Education: The CDIO Approach", Springer, 2007.

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