CDIO– can it be adapted for Distance Education?

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BACKGROUND

CDIO – Conceive, Design Implement and Operate has become a hot topic in curriculum design in recent years. It is championed as "an innovative educational framework for producing the next generation of engineers" (http://www.cdio.org/). The framework realizes the widen gap between engineering education and graduate practices. The basis of the syllabus, which claims can be adapted to any organization or educational institution, stresses the development of engineering fundamentals set in design and construct projects. To date, all institutions which have implemented CDIO and undertaken comprehensive evaluations of its success, have been traditional educational institutions with the standard cohort of oncampus students working in standard facilities in face-to-face teaching practices. However, in the rush to tap into new markets many institutions are venturing into the area of online and distance education. This places many different demands on students and academics and has further consequences for curriculum and assessment design.

PURPOSE

This paper investigates opportunities and barriers to implementing the CDIO framework to distance and online education.

DESIGN/METHOD

This paper is largely a literature review on CDIO, CDIO standards, and its application in distance education. It covers the area of distance and online education and Work Integrated Learning and how these principles can be applied to CDIO.

RESULTS

CDIO, whilst not the only avenue to develop a holistic curriculum, it does offer a well-developed and internationally supported framework. By using the framework along with aspects of virtual teamwork, it supported communication tools, and WIL, it offers a robust and innovative way to develop key graduate attributes in a diverse cohort of students. Students can utilise and expand on their work and life experience and industry becomes a key stakeholder in the learning partnership. By supporting appropriate placements for students and providing input into the curriculum and projects, distance education students may be able to overcome many of the barriers previously discussed.

CONCLUSIONS

In conclusion the authors demonstrate that with careful curriculum and assessment planning, making use of current technology and the appropriate learning theories of active and collaborative learning CDIO can be implemented successfully for distance education and several strategies are discussed. Whilst the implementation is not without problems it still can provide significant benefits for an increasingly diverse student cohort. CDIO deliver key graduate attributes as required by accreditation bodies as well as providing incentives for teaching staff to up-skill in both technical knowledge and teaching and learning principles.

KEYWORDS
CDIO; distance education; online education; graduate attributes.

Introduction

CDIO – Conceive, Design Implement and Operate has become a hot topic in curriculum design in recent years. It is championed as "an innovative educational framework for producing the next generation of engineers" (http://www.cdio.org/). The CDIO framework recognizes that Engineering education and real-world demands on engineers have drifted apart in recent years and the framework endeavors to close this gap. The goals of the CDIO initiatives are to:

- *Educate students to master a deeper working knowledge of the technical fundamentals;*
- *Educate engineers to lead in the creation and operation of new products and system; and*
- *Educate future researchers to understand the importance and strategic value of their work*.

The basis of the syllabus, which can be adapted to any organization or educational institution, stresses the development of engineering fundamentals set in design and construct projects. All institutions that have implemented CDIO successfully to date, appear to be traditional educational institutions with the standard cohort of on-campus students, working in standard facilities using face-to-face teaching practices.

However, in the rush to tap into new markets many institutions are venturing into the area of online and distance education (Brodie, 2006). This mode of delivery places different demands on both students and academics, and has further consequences for curriculum and assessment design. In addition, distance, part time and online educational modes present greater opportunities for a more diverse student cohort to undertake tertiary education. This additional student diversity must also be factored into curriculum design as this new cohort of students will bring significant diversity to the 'virtual' classroom. This can be successfully harnessed and used constructively within the curriculum with good curriculum design.

This paper investigates opportunities and barriers to implementing the CDIO framework for distance and online education providers.

Distance and Online Engineering Education

Keegan (1986) defines distance education as the combination of the two fields of Distance Teaching and Distance Learning. Distance teaching applies to the development of teaching materials, the instructional design and the pedagogy of the delivery including assessment strategy. The design must cater to the target group of students and include their general education and previous study experiences as well as specific prior knowledge of the subject.

Course design, however, does not always translate to learning, as seen from the students' perspective. Distance education is a suitable term to bring together both the teaching and learning elements and can effectively free students from the traditional academic structure of lectures and tutorials at a university campus. With the massification of education, changing economic and social patterns, and the boom in technology, particularly personal computers and the internet, distance and online education have become growth industries in Australia and worldwide.

This growth has been supported by the recent maturing of research into learning within an online environment (Kehrwald et al, 2005). Consequently, modern online courses are now usually designed on well recognised theoretical foundations. However, the literature reports on the 'failed uptake of eLearning in America' (Zemsky & Massy, 2004) and suggests, at least from a student perspective, that eLearning has not developed as fast as anticipated (Pond, 2003; Fresen, 2008). The literature also suggests that this outcome is due to a failure to adequately investigate and address the needs of distance education students (Pond, 2003).

Today's distance education students are interested in professional qualifications and "learning that can be done at home and fitted around work, family, and social obligations" (Bates, 2004). They require more flexibility in program structure to accommodate their other responsibilities and hence implementing any curriculum change like CDIO must be able to accommodate these needs.

A decade ago, the predicted trend was for a growth in ‘blended learning.’ It was, according to the then president of Pennsylvania State, “the single-greatest unrecognized trend in higher education today” (Young, 2002, p. 33 as cited by Graham, 2004).

There are three main themes in defining exactly what is meant by blended learning (BL): 1) combining instructional modalities; 2) combining instructional methods; and 3) combining online and face-to-face instruction (Graham, Allen, and Ure, 2003). Graham (2004) poses arguments for the first two of these models and proposes that:

> *“BL is the combination of instruction from two historically separate models of teaching and learning: traditional F2F learning systems and distributed learning systems. It also emphasizes the central role of computer-based technologies in blended learning.”*

Whilst the proposed boom in blended learning has not yet eventuated, especially in Australia, the model does offer many opportunities for CDIO.

Work Integrated Learning (WIL)

Work Integrated Learning offers a number of advantages to implementing CDIO in the distance mode. Crucial to CDIO is input from industry with respect to formulating real world design problems and industry also gives opportunity for distance students to engage more readily in the design and construct phase of CDIO.

Although WIL is a somewhat generic term covering a variety of approaches integrating aspects of learning within the workplace through a crafted curriculum, it is “seen by universities both as a valid pedagogy and as a means to respond to demands by employers for work-ready graduates, and demands by students for employable knowledge and skills” (Patrick et al, 2008).

The main barriers to implementing and maintaining WIL as identified by universities are: the difficulty and expense in finding quality placements for students; workload and time constraints for staff; and, the inflexibility of university timetables to allow sufficient time for students in the workplace (Patrick et al, 2008).

A key aspect of successful WIL is the partnership, communication and assuming definite responsibilities between the student, the work organisation and the university (Martin & Hughes, 2009).

With the large proportion of distance students already employed in the engineering workplace and often supported by their employer to undertake study to formalise their position, some of the barriers and resources needed to undertake successful WIL can be minimised allowing staff to focus support on students who are not in the position to undertake work-based activities.

Background CDIO Literature

The CDIO initiative was launched in 2000 between MIT and three Swedish Universities and now has a significant following across the world. The initiative was born from the need to bridge the widening gap between the university approach to education and industry requirements. Universities focused on transmitting to students an ever growing body of knowledge whilst industry required more transferable skills required for engineers effectively operate in the real world and to continue their career progression (www.cdio.org).

In 2001 MIT published “The CDIO Syllabus: A Statement of Goals for Undergraduate Engineering” (Crawley, 2001). The document:

> *“…essentially constitutes a requirements document for undergraduate engineering education. It is presented here as a template plus a process, which can be used to customize the Syllabus to any undergraduate engineering program.”* (Crawly, 2001, p1)

It recognises, as do many other approaches to engineering education and curriculum design, that engineers need a wide range of skills and knowledge and much of the engineers craft comes from *practice* and experience. Whilst this practice has a sound foundation in theory, it is application of this theory to real world, everyday problems that is *engineering.*

Thus, from examining the practice of engineering, a statement defining why a board range of skills in a graduate engineer was required in order to overarch curriculum design was derived:

> *"Graduating engineers should be able to conceive-design-implement-operate complex value-added engineering systems in a modern team-based environment."* (Crawley 2001, p2)

The syllabus sets out to clearly define a "clear, complete consistent set of goals for undergraduate engineering education" to be implemented by universities. The syllabus is designed around 12 Standards which includes a program evaluation standard (Man-li, 2008). Critical to the integration of CDIO to online and distance education are:

- STANDARD 2: CDIO Syllabus Outcomes
- STANDARD 3: Integrated Curriculum
- STANDARD 4: Introduction to Engineering
- STANDARD 5: Design-Build Experiences
- STANDARD 6: CDIO Workspaces
- STANDARD 7: Integrated Learning Experiences
- STANDARD 8: Active Learning

There is a significant amount of literature around implementing CDIO and its subsequent evaluation with respect to student perspectives, student learning and graduate outcomes (e.g. Crawley, 2007; Berggran, 2003; Bankel, 2005; Gu, 2006; Lynch et al, 2007; Zha, 2008). Thus, there is a large pool of resources which are freely available and a community of advocates willing to share experiences and expertise (http://www.cdio.org/implementing-cdio/standards/12-cdio-standards).

However, it is important that CDIO is not just seen as an 'add on' to the curriculum. By definition CDIO is complete approach to curriculum design. It requires input from industry, employers and other key stakeholders as shown in Figure 1 below (Armstrong, undated).

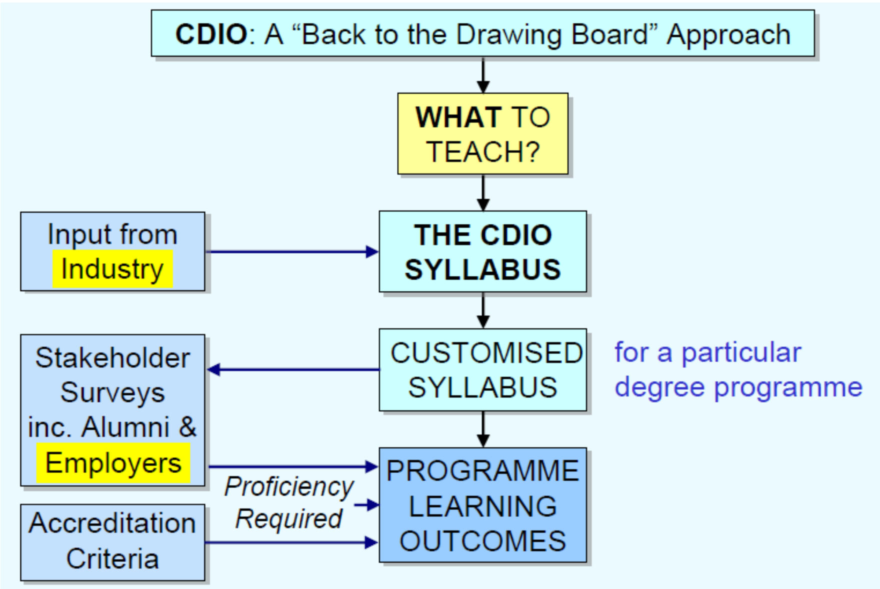

Figure 1 The CDIO Approach (Armstrong, undated)

CDIO Evaluation

As with any new curriculum project or program, evaluation and continuous monitoring and improvement are critical. Thus Standard 12: CDIO Program Evaluation must also be reviewed and modified to suit an online setting. Gray (2012) proposes five quality assurance processes to ensure consistency and quality of the CDIO approach. However, alternative more comprehensive evaluation systems may be better suited to the complexity of CDIO.

Program Logic offers an alternative program evaluation method providing a more comprehensive approach to evaluation including:

- Inputs: resources that go into the program, both tangible and intangible.
- Outputs: the activities that are undertaken during the program and who or what they impact on.
- Outcomes: the actual changes that result from the program.
- Assumptions: the beliefs about the program and the context of the program.
- External factors: factors which influence the program.

over the domains of appropriateness, effectiveness, efficiency, impact, and sustainability adapted from the Program Logic model of evaluation (University of Wisconsin , (2011 and undated). Program Logic would be used for all evaluation of the critical areas of enhancing faculty teaching skills (Standard 10) and ongoing monitoring and evaluation from all perspectives. Whilst the methodology is complex, once designed the plan gives a systematic framework for monitoring and continuous improvement.

CDIO and Distance Education

There are a variety of reports in the literature regarding CDIO and its implementation in distance or online education. Given that Australia makes extensive use of distance education in one form or another, it is no surprise that much of this literature is of Australian origin.

However, the link between CDIO and distance education is tenuous. Much of the existing literature focuses on the *teamwork* aspect of the curriculum e.g. Ferguson (2006, 2008); Zhuge (2013). These curriculum developments rely on technology to facilitate both synchronous and asynchronous communication between dispersed team members. Teams work collaboratively on problems or projects but it could be argued that they essentially do not conform entirely to the CDIO principles. In reference to the 12 standards and the particular standards identified earlier pertinent to distance education, Table 1 indicates standards necessary to implement CDIO and evidence from the literature that these standards are being met.

However, distance and online education still have much scope for implementation of the CDIO syllabus. The majority of distance education students are employed, in some form, within the engineering industry. Indeed these students can bring much relevant current industry practice to the classroom. Industry based work offers many opportunities to engage students in the four phases of the product process or system lifecycle espoused by CDIO. The difficulty lies in capturing these opportunities equitably for the entire student cohort; maintaining standards and quality of work and appropriate assessment practices.

Table 1 CDIO standards addressed in the literature

CDIO Standards	Demonstrated in the literature for distance and online education
STANDARD 2: CDIO Syllabus Outcomes	Not fully demonstrated or discussed in the literature
STANDARD 3: Integrated Curriculum	Not fully demonstrated in the literature but projects do tend to require a wide ranges of skills and knowledge.
STANDARD 4: Introduction to Engineering	Yes, evidence in literature that projects under the CDIO heading are used for an introduction to engineering
STANDARD 5: Design-Build Experiences	CDIO in distance mode is normally confined to design aspect only
STANDARD 6: CDIO Workspaces	Partly. Distance education has a ‘virtual workspace’ but collaborative efforts on design software etc is limited
STANDARD 7: Integrated Learning Experiences	Yes, evidence in literature that the projects do seek to integrate a range of skills and knowledge
STANDARD 8: Active Learning	“Active learning” is difficult to evaluate in distance and online learning

Discussions

Technology has enabled industry to utilise more dispersed engineering teams, collaborating online. Whilst industry used to call for engineering graduates to have better teamwork, communication and collaborative skills, it is likely that the call will soon to be to develop these skills in an online environment (Jamison, 2007a &b, Thoben & Schwesig, 2002; Kehrwald et al, 2005). Virtual learning teams, supported by technology are also making an appearance in the tertiary sector. Whilst the learning outcomes of these experiences are contested and virtual teamwork is full of complex challenges, the system does allow normally isolated distance students to interact with fellow students. Given the diversity of distance student cohorts, effectively utilising diversity through peer assisted learning offers greater learning opportunities.

Often in implementing curriculum academics focus on the ‘technical knowledge’. They use a passive transmission mode despite the plethora of literature which emphasises active learning. CDIO emphasises a more holistic approach, capturing the diverse ranges of skills that a practising engineer required.

Armstrong (undated) in Figure 2 succinctly shows the range of contexts and skills required by the practising engineer. Apart from the technical knowledge, very few of the other areas are effectively taught in universities settings, and in particular in traditional classrooms. By utilising distance, online or blended learning and harnessing the diverse skills of the student cohort, many of these aspects can be captured.

CDIO, whilst not the only avenue to develop a holistic curriculum, it does offer a well developed and internationally supported framework. By using the framework along with aspects of virtual teamwork, IT supported communication tools, and WIL, it offers a robust and innovative way to develop key graduate attributes in a diverse cohort of students. Students can utilise and expand on their work and life experience and industry becomes a key stakeholder in the learning partnership. By supporting appropriate placements for students and providing input into the curriculum and projects, distance education students may be able to overcome many of the barriers previously discussed.

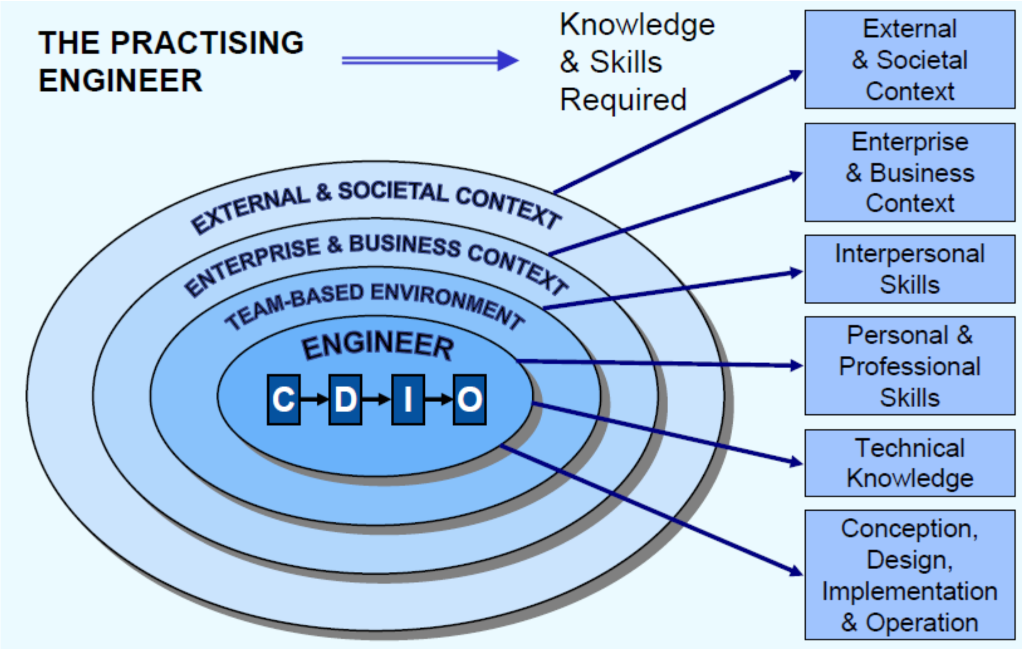

Figure 2 - The Total Requirement (Armstrong (undated)

Conclusions

In conclusion, the authors suggest that with careful curriculum planning, consultation and engagement with key stakeholders, making use of current technology, and by applying appropriate learning theories of active and collaborative learning, CDIO can be implemented successfully for distance, online and blended educational delivery modes. Whilst the implementation will not be without problems it can still provide significant benefits for an increasingly diverse student cohort. CDIO delivers key graduate attributes as required by accreditation bodies as well as providing incentives for teaching staff to up-skill in both technical knowledge and teaching and learning principles. The authors are currently exploring opportunities to implement and evaluate CDIO distance learning initiatives. It is anticipated that we will be able to report on the successes, or otherwise, in the near future.

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