CDIO in Singapore Polytechnic: Enhancing Innovation in Engineering Education

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Abstract: This paper describes and analyses a 10-year educational development process of redesigning the engineering programmes at Singapore Polytechnic (SP) using the CDIO framework. CDIO (Conceive-Design-Implement-Operate) is a worldwide initiative for reforming engineering programmes towards a multidisciplinary, hands-on curriculum that emphasizes real world applications. Adopted by 120 educational institutions worldwide, the initiative aims to equip students with deep technical knowledge and engineering skills required by industry. These include personal and professional skills and attributes; interpersonal skills of teamwork and communication; and engineering design and product building skills. Singapore Polytechnic (SP) joined the CDIO collaboration and adapted the framework for its 15 full-time engineering programmes in 2004. In this paper, the authors will share the milestones in Singapore Polytechnic's journey of engineering education curricula reform and the outcomes of the reform on its programmes and graduates. They will revisit the objectives of the educational development, the changes that were introduced, and the review the outcomes. Critical success factors for sustainable educational development will be shared.

Keywords: CDIO, engineering education development, critical success factors

INTRODUCTION

CDIO is a worldwide initiative that was conceived by Massachusetts Institute of Technology (MIT) in Cambridge Massachusetts in the late 1990 in collaboration with 3 Swedish universities: Chalmers Technology, Linkoping University and the Royal Institute of Technology (Crawley, et al. 2007). The initiative was funded by the Wallenberg Foundation. The initiative was a response to industries', governments' and academia concern about the greater emphasis on the teaching of theory in engineering. As such, engineering graduates lacked essential practical engineering skills and attributes necessary for real world practice. As Crawley et al (2007) summarized:

...we identified an underlying critical need – to educate students who are able to Conceive-Design-Implement-Operate complex, value added engineering products, processes and systems in a modern, team-based environment. It is from this emphasis on the product, process, or system lifecycle that the initiative derives its name-CDIO. (p.1)

In 2002-2003, SP’s management realized the need to produce graduates who are more Creative, Innovative and Entrepreneurial (CIE) and embarked on its journey to transform its engineering programs. Being the first Asian higher educational institution to join the CDIO initiative in 2004, the team of engineering faculty had to customize the CDIO educational model which was conceived in a western university context to the Asian and polytechnic context of Singapore. From 2006 onwards, there were active experimentation, innovation and adoption of the CDIO range of competencies and best practices by 15 engineering programs. This was the start of a 10-year educational development process which involved
changes in the design of curricular, pedagogic approaches and learning spaces.

OBJECTIVES

Curriculum reform and innovation are essential to better prepare our students for the changing economic and social needs of a country. It is also a reflection of the responsibility of educators to incorporate new evidence based research and understanding about human learning into their practices. Very often, curricula reforms are perceived as transient and to be discarded and replaced by the next initiative. Overtime, faculty become weary and fatigue by the numerous changes they are expected to implement in their teaching. The need for a sustainable and enduring educational development process is necessary.

Educational development needs to be viewed as a long-term strategic process involving meaningful enhancements and continuous faculty and stakeholder engagement for it to be sustainable and enduring. Key to the process is strong institutional support from leaders and resource personnel to establish appropriate cultural and structural contexts as well as support for capability building (Malmqvist, et al., 2010).

The aim of this study is to examine the experiences and outcomes from a long-term education development process. In particular, this paper aims to identify the critical success factors for achieving a sustained programme development and to propose improvements in education development practices.

METHODS

Education development is shaped by numerous factors. It is influenced by the needs and vision of the nation, institution as a whole and the school the faculty belongs to and involves cultural, structural and capability factors. For this paper, we have adopted a qualitative research approach. This approach involves the study of the implementation of a case of an education reform to identify the critical success factors. Data of the implementation was gathered from multiple sources and individual and group interviews conducted to map out the process and outcomes of the case. Additional information like a 3 year programme evaluation which included students’ and faculty perception and learning, and feedback from external reviewers were also considered.

RESULTS

Guided by a set of customized skillset for the modern engineer and 12 CDIO best practices, 15 engineering programmes from the Schools of Electrical and Electronic Engineering, Mechanical and Aeronautical Engineering, Chemical and Life Sciences and Architecture and the Built Environment were revised and restructured. The 12 CDIO best practices address:

- Programme philosophy (Standard 1)
- Curriculum outcomes and design (Standards 2, 3 & 4)
- Design-implement experiences and workspaces (Standards 5 & 6)
- Teaching and learning approaches (Standards 7 & 8)
- Faculty development (Standards 9 & 10)
- Assessment and Programme evaluation (Standards 11 & 12)
Some of the revisions made include the integration of the CDIO skills of personal and professional skills and attributes; interpersonal skills of teamwork and communication; and product and process design and build skills into the programmes. In all programmes, an Introduction to Engineering module was introduced to provide students with opportunities to develop the basic conceive, design, implement and operate skills and link and integrate knowledge across the courses to stimulate interest in, and strengthen students’ motivation for, the field of engineering. Existing assessment schemes were also reviewed and revised accordingly. Teaching of the revised programmes began in April 2008 with the first year modules. After 8 years of implementation, the CDIO has taken root in Singapore Polytechnic.

A longitudinal study of faculty and student feedback on the initial version of CDIO implementation was positive. Throughout the 8 years of implementation, the original framework has been enhanced to include the adoption of design thinking methodology to promote a user-centred approach to conceiving and designing solutions; an emphasis on attributes like sustainability, appropriate technology and a global mindset; integration of principles of self-determination theory (Deci & Ryan, 2000) in learning activities; and adoption of EduTech for teaching and learning.

The results of the CDIO implementation have been positive. The CDIO framework provided a systematic approach to curriculum development and also provided faculty with a common language and vision for engineering education. This systematic and systemic approach adopted by the Diploma of Chemical Engineering to revise their curricula recognized by the Institute of Chemical Engineers. In 2012 and 2015, SP was awarded the Excellence in Education and Training in Chemical Engineering by IChemE Singapore for adopting the CDIO framework to deliver the best educational experience to students. SP was identified in a 2012 study by the Royal Academy of Engineering (UK) and MIT on “Achieving excellence in engineering education: the ingredients of successful change” as one of 20 institutions worldwide with programmes of educational change in engineering that is highly regarded (Graham, 2012).

More engaging, real world learning opportunities based on the conceive-design-implement-operate model were introduced into the curriculum. As a consequence of its practical, real-world approach, these activities better engaged students in their learning and equipped them with deeper engineering skills and habits of mind. Furthermore, the design thinking methodology strengthened their abilities to generate innovative concepts and products. Overall, they were better able to work on real world engineering projects and generate innovative products.

CONCLUSION

Curriculum reform is multifaceted. There are many factors that influence its implementation and hence sustainability. Unpinning the success of the CDIO implementation in SP is the structural, cultural and management support provided by the CDIO framework and the institution. The CDIO standards and best practices provided a systematic approach to the development of a coherent interconnected curriculum based on stakeholders and employers feedback. The framework also provided faculty with a clear purpose and strategy for curriculum development. It was important that the framework was not prescriptive but customizable to the institution’s context. Early gathering of student and faculty feedback provided faculty with information on the progress and impact of the changes. This gave faculty a sense of ownership of the changes and motivation to continue. Strong management support and carefully considered enhancements gave faculty the confidence that the framework was not transient but was the foundation on which other meaning educational developments can be
incorporated. This allowed faculty to see that educational developments are on-going and require constant monitoring and experimentation to ensure its success, continuity and relevance. Finally, strong faculty competence development programmes and learning opportunities aimed at providing lecturers with the necessary skills to design curricula and teach effectively need to be considered. Continuous sharing of good practices among faculty and with faculty from other institutions reinforced the purpose and importance of the innovative curriculum changes.

REFERENCES


