Is it possible to adapt CDIO for distance and online education?

Terry Lucke, Lyn Brodie, Ian Brodie, Siegfried Rouvrais

IT IS POSSIBLE TO ADAPT CDIO FOR DISTANCE AND ONLINE EDUCATION?

Terry Lucke,[1] Lyn Brodie,[2] and Ian Brodie[2]

[1]University of the Sunshine Coast, Australia
[2]University of Southern Queensland, Australia

Siegfried Rouvrais[3]

[3]Telecom Bretagne, Institut Mines-Télécom, European University of Brittany, France

ABSTRACT

The CDIO approach to engineering education 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”. The CDIO framework recognizes that engineering education and real-world demands on engineers have drifted apart in the 2000’s and the framework endeavours to close this gap. Among its standards, the basis of the CDIO syllabus standard 2, which can really be adapted to any organization or higher educational institution, stresses the development of engineering fundamentals set in the lifecycle of projects. However, it appears that most of the institutions that have successfully implemented CDIO to date are generally traditional with the standard cohort of on-campus students, working in standard facilities using most often face-to-face teaching practices. As the search for new education markets intensifies, many institutions are now starting to venture into the area of online and distance education. This mode of delivery places very different demands on both students and academics, and it also 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.

KEYWORDS

Distance Education, Blended Learning, Online Learning Environment, CDIO Standards 2 - 8

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

In the rush to tap into new markets, many institutions are now venturing into the area of online and distance education (June & Leong, 2006; Brodie, 2006). This mode of delivery places different demands on both students and academics, and has further consequences for curriculum and assessment design (Levy, 2003). 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 program design methods and processes. After a literature review on distance and online education and an overview presentation of the some of the CDIO models and processes, this paper investigates opportunities and barriers to implementing the CDIO framework for distance and online education providers.

DISTANCE AND ONLINE ENGINEERING EDUCATION

Keegan (1986) defined 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.

Phipps and Merisotis (2000) assert that the effectiveness of distance learning must be measured in results – *quality learning* – by students. 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 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).

Teaching in an online environment requires specific competencies and skills sets of skills and not all faculty are suited for the online environment (Smith, 2005). 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 supported by CDIO framework guidelines 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, and most often rely at project level rather than fully integrative level (Rouvrais et al, 2005), the model does offer many opportunities for CDIO.

WORK INTEGRATED LEARNING

Work Integrated Learning (WIL) offers a number of advantages to implementing CDIO in the distance mode. Input from industry with respect to formulating real world design problems is vital for CDIO and it also gives the 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). 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).

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).

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 global following. 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

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."* (Crawley, 2001)

It recognises, as do now 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).*

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 (Manli, 2008). The standards most relevant 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). Figure 1 outlines the typical CDIO curriculum design process (Loyer et al., 2011).

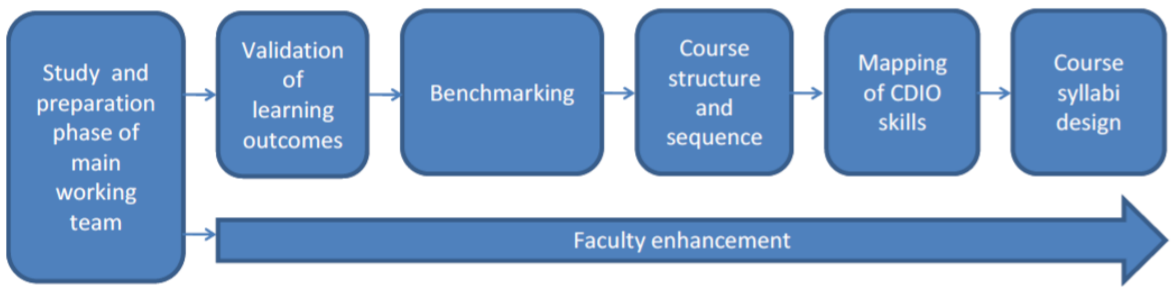

Figure 1. Curriculum design process (Loyer et al., 2011)

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. The five quality assurance processes begin with the application to become a CDIO Collaborator and include self-evaluation, certification, and accreditation based on the CDIO Standards. However, alternative more comprehensive evaluation systems may also be used and may be better suited to the complexity of offering CDIO education online.

CDIO AND DISTANCE EDUCATION

There is a number 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); Ferguson et al. (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.

Table 1. CDIO Standards addressed in the literature for blended learning

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 range 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

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.

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 (Jamieson, 2007; 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.

Academics often focus on the 'technical knowledge' when implementing curriculum. They still sometimes use a passive transmission mode, despite the plethora of literature which emphasises active learning. CDIO programs promote a more holistic approach, capturing the diverse range of skills required by practising engineers. Armstrong and Niewoehner (2008) succinctly show the range of contexts and skills required by the practising engineer in Figure 2. Apart from the technical knowledge, it appears that only 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.

While CDIO is not the only way to develop a holistic, industry-focussed curriculum, it does offer a well-developed and internationally supported framework for development. 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.

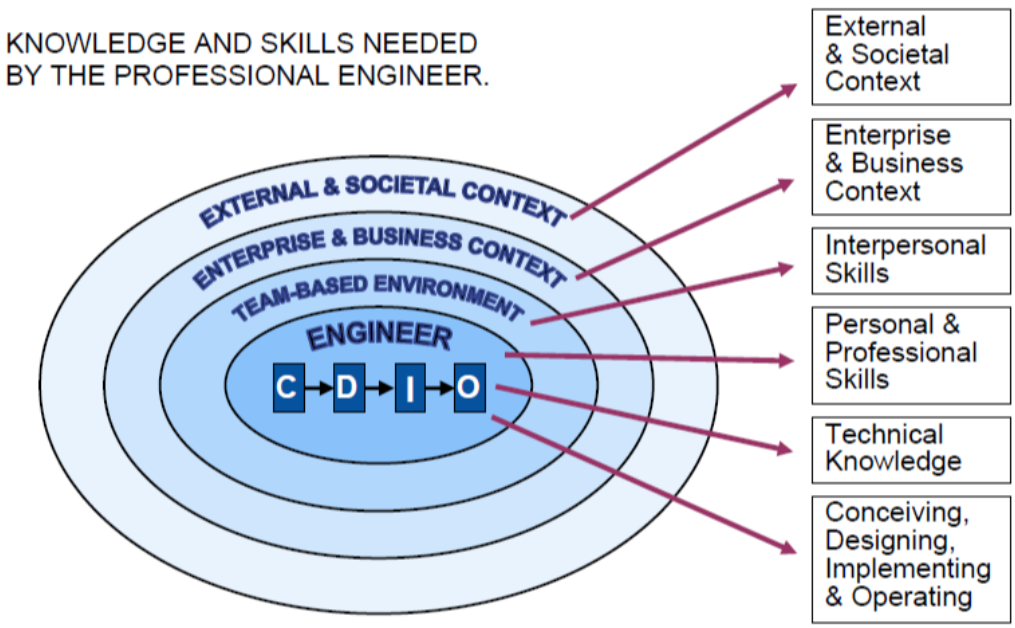

Figure 2. The Rationale for the Main Headings of the CDIO Syllabus
(Armstrong & Niewoehner, 2008)

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 the key graduate attributes 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 they will be able to report on the successes, or otherwise, in the near future.

REFERENCES

Armstrong, P. and Niewoehner, R. 2008. The CDIO approach to the development of student skills and attributes. *4th International CDIO Conference*, Hogeschool Gent, June 16-19, Gent, Belgium.

Bankel, J. 2005. Benchmarking engineering curricula with the CDIO syllabus. *International Journal of Engineering Education* 21(1), 121-133.

Bates, A.W. 2004. *Managing Technological Change: Strategies for University and College Leaders*. Jossey-Bass, San Francisco.

Berggren, K. F., Brodeur, D. R., Crawley, E. F., Ingemarsson. I., Litant, W. T., Malmqvist, J. and Östlund, S., 2003. CDIO: An International Initiative for Reforming Engineering Education. *World Transactions on Engineering and Technology Education*, 2(1), 49-52, 2003

Brodie. L. 2006. Problem Based Learning in the Online Environment – Successfully Using Student Diversity and e-Education. *Internet Research 7.0: Internet Convergences*, Brisbane, Qld, Australia.

Crawley, E. (2001) The CDIO Syllabus: A Statement of Goals for Undergraduate Engineering Education: http://www.cdio.org/files/CDIO_Syllabus_Report.pdf

Crawley, E.F., Malmqvist, J., Östlund, S., & Brodeur, D.R. 2007. *Rethinking Engineering Education*: *The CDIO Approach*. Springer, New York.

Ferguson, C. 2006. Attributes for Australian mechanical engineers through proximal and distance education *(Doctoral Thesis). Deakin University*. http://dro.deakin.edu.au/eserv/DU:30023284/ferguson-attributesforaustralian-2006.pdf

Ferguson, C., Goodhew, P., Endean, M., Brodie, L., Palmer, S. and Murphy, M. 2008. An investigation into the adoption of CDIO in distance education. EE2008 International Conference on Innovation, Good Practice and Research in Engineering Education, 12–14 July 2008, Loughborough, UK.

Fresen, J. 2008. Factors Influencing Lecturer Uptake of E-Learning. *Teaching English with Technology*, Special Issue on LAMS and Learning Design, 11(1), 81-97.

Graham, C.R., Allen, S., and Ure, D. 2003. Benefits and challenges of blended learning environments. In M. Khosrow-Pour (Ed.), *Encyclopaedia of Information Science and Technology I-V*. Hershey, PA: Idea Group Inc.

Graham. C. 2004. Blended Learning Systems: Definition, Current Trends and Future Directions. In Bonk, C. J. & Graham, C. R. (Eds.). *Handbook of blended learning: Global Perspectives, local designs*. Pfeiffer Publishing, San Francisco, USA.

Gray, P.J. 2012. CDIO Standards and Quality Assurance: From Application to Accreditation. *Int. Journal of Quality Assurance in Engineering and Technology Education* (IJQAETE), 2(2), 1-8.

Gu, P., Lu, X., Xiong, G., Li, S. and Shen, M. 2006, The development of design directed engineering curriculum based on the CDIO framework. *2nd International CDIO Conference*, 13-14 June, 2006, Linkoping University, Sweden.

Jamieson, L. 2007, Engineering Education in a Changing World. *IEC DesignCon Conference*, January 31, Santa Clara, California, USA.

June, H.T. and Leong, H. 2006. Implications of E-Learning on Learning and Teaching in Higher Education, *2nd International CDIO Conference*, 13-14 June, 2006, Linkoping University, Sweden.

Keegan, D. 1986. *The foundations of distance education*. Croom Helm, Kent, UK.

Kehrwald, B., Reushle, S., Redmond, S., Cleary, K., Albion, P. and Maroulis, J. 2005. Online pedagogical practice in the Faculty of Education at the University of Southern Queensland, *University of Southern Queensland*, Toowoomba, Australia: http://eprints.usq.edu.au/131/

Levy, S. 2003. Six factors to consider when planning online distance learning programs in higher education. *Online Journal of Distance Learning Administration*, 4(1). http://www.westga.edu/%7Edistance/ojdla/spring61/levy61.htm

Loyer, S., Muñoz, M., Cárdenas, C., Martínez, C., Cepeda, M. and Faúndez, V. 2011. A CDIO Approach to Curriculum Design of Five Engineering Programs at UCSC. *7th International CDIO Conference*, Technical University of Denmark, June 20 - 23, 2011, Copenhagen, Denmark.

Lynch, R., Seery, N. and Gordon, S. 2007. An evaluation of CDIO approach to engineering education. *International Symposium for Engineering Education*, Dublin, Ireland, 2007, 13-21.

Manli, L. 2008. An Historical Interpretation of CDIO and its Application Prospects. *Tsinghua Journal of Education*, 5, 78-87. (in Chinese)
Martin. A. and Hughes, H. 2009. How to Make the Most of Work Integrated Learning: A Guide for Students, Lecturers and Supervisors, *Massey University*, Palmerston North, New Zealand: http://www.waceinc.org/papers/How%20To%20Make%20The%20Most%20of%20Work%20Integrated%20Learning.pdf

Patrick, C.J., Peach, D., Pocknee, C., Webb, F., Fletcher, M. and Pretto, G. 2008. The work integrated learning report: A national scoping study. Australian Learning and Teaching Council Final Report. Queensland University of Technology, Australia: http://www.apjce.org/files/APJCE_10_3_189_201.pdf

Phipps, R., and Merisotis, J. 2000. Quality on the line: Benchmarks for success in Internet-based distance education. Washington, DC: The Institute for Higher Education Policy. http://files.eric.ed.gov/fulltext/ED444407.pdf

Pond, W.K. 2003. Lifelong Learning-The Changing Face of Higher Education, *eLearning Summit*, La Quinta Resort, California.

Rouvrais S., Maillé P., Gilliot J-M., Madec G., and Guyomar A. 2005. Migrating Learn-by-Doing Engineering Curricula to Blended Learning. In Proceedings of ED-MEDIA'05, World AACE Conference on Educational Multimedia, Hypermedia and Telecommunications, Kommers P. and Richards G. (Eds), pages 4053-4059. Montreal, Canada.

Smith, C. 2005. Fifty-One Competencies for Online Instruction. *Journal of Educators Online*, 2(2), July 2005. http://www.thejeo.com/Archives/Volume2Number2/SmithFinal.pdf

Thoben, K-D. and Schwesig, M. 2002. Meeting Globally Changing Industry Needs in Engineering Education. ASEE/SEFI/TUB International Colloquium - Global Changes in Engineering Education. October 1-4, Berlin, Germany.

Zemsky, R. and Massy, W.F. 2004. Thwarted innovation: what happened to e-learning and why? *Final report for the weatherstation project of the Learning Alliance*, University of Pennsylvania: http://www.immagic.com/eLibrary/ARCHIVES/GENERAL/UPENN_US/P040600Z.pdf

Zha, J. 2008. On CDIO Model under Learning by Doing Strategy. *Research in Higher Education of Engineering*, 3:1-6.

Zhuge. Y., Brodie. L., Mills. J. 2012. The Effectiveness of Team Project Work for Distance Education Students. 8th Intern. CDIO Conference, July 1-4, Queensland University of Technology, Brisbane.

BIOGRAPHICAL INFORMATION

Terry Lucke is Associate Professor of Hydraulic and Civil Engineering at the university at the University of the Sunshine Coast in Australia. His main teaching areas are Fluid Mechanics, Hydraulics and Road and Drainage Design. Terry is very involved in engineering education research, particularly in the blended learning environment, using the flipped classroom approach and the CDIO Initiative. In 2013, Terry's teaching was recognised nationally by winning a prestigious Australian Government Office of Learning and Teaching's Citation Award for Excellence in Teaching and Outstanding Contributions to Student Learning. Terry also leads a team of researchers in the USC Stormwater Research Group at USC.

Lyn Brodie is an Associate Professor, the Associate Dean (Students) in the Faculty of Health, Engineering and Science at the University of Southern Queensland (USQ) and Chair of the University Academic Board. Her research interests include Engineering Education, Problem Based Learning, Assessment, Curriculum Design and The First Year Experience. Lyn is the Director of the Engineering Education Research Group at USQ and her work has been recognised through several national awards. Lyn was president of the Australasian Association for Engineering Education (AAEE) in 2013. She currently sits on several national committees of Engineers Australia and is also a Fellow of Engineers Australia.

Ian Brodie is Senior Lecturer (Public Health Engineering) at the University of Southern Queensland in Australia. Prior to joining USQ, Ian worked in industry for 20 years as a water engineering consultant. His main teaching areas are hydrology and water resources engineering. Ian is the Environmental and Agricultural Engineering discipline leader within the School of Civil Engineering and Surveying and his research interests are in stormwater, floods and engineering education.

Siegfried Rouvrais is Associate Professor in the CS Department of Institut Mines-Télécom Bretagne and he is jointly affiliated with the IRISA research unit of the French *Centre Nationale de la Recherche Scientifique* (CNRS). He co-leads the French TREE research group on Engineering Education Research (http://recherche.telecom-bretagne.eu/tree). Author of several international publications in Engineering Education, he organized the international CDIO 2012 Fall meeting and was elected to the board of CDIO international council member in 2013. In 2002-05, he was workpackage leader in a Leonardo da Vinci European project on "Internet-based vocational training of communication students, engineers, and technicians" (http://www.invocom.et.put.poznan.pl/). His current scholarly interests are in Quality Enhancement, methods and processes for systemic Higher Education changes.

Corresponding author

Associate Professor Terry Lucke
University of the Sunshine Coast
90 Sippy Downs Drive
Sippy Downs 4556
QLD, Australia
+61-7-5456 5185
tlucke@usc.edu.au