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Integrating Assessment and Design Activity in Engineering Education: A Proposed Synthesis of Adaptive Comparative Judgement and the CDIO Framework

Tomás Hyland, Seamus Gordon and Donal Canty
University of Limerick, Limerick, Ireland

Jeffrey Buckley
KTH Royal Institute of Technology, Stockholm, Sweden

Niall Seery
Athlone Institute of Technology, Co. Westmeath, Ireland
and KTH Royal Institute of Technology

Abstract

One of the leading frameworks in engineering education specifically associated with design based competencies is the CDIO framework. This has been incorporated internationally into many institutions offering engineering education courses. Characterized by four unique stages, the CDIO framework affords an ideal scenario to incorporate a continuous assessment model. This paper presents a proposed synthesis between CDIO and Adaptive Comparative Judgement (ACJ). In particular, the opportunity to provide feedback through the ACJ system is theorized to have potentially positive educational effects. As part of a larger study, this approach is in the process of being refined prior to implementation as a pilot study for feasibility which will ultimately be succeeded by large-scale implementation to determine any potentially positive effect sizes.

Introduction

Educational assessment is complex. There are a variety of approaches to assessment such as summative, normative and ipsative, and there are a variety of functions of assessment such as to provide feedback to learners, to act as a diagnostic tool to inform educators, and to serve as a matriculation system for further education. Not only is assessment complex, but it both directly and indirectly through associated actions such as feedback has a high effect size on learning (Hattie, Biggs, & Purdie, 1996; Vaessen et al., 2017). The effects of assessment from both pedagogical and psychological perspectives are well documented with notable attributes being affected such as the learning process (Hattie & Timperley, 2007), assessment related anxiety (Huxham, Campbell, & Westwood, 2012), self-esteem (Betts, Elder, Hartley, & Trueman, 2009), and approaches to learning (Reeves, 2006). It is therefore critical that educators are able to negotiate this space strategically to ensure the educational needs of learners are met without inducing any potential negative outcomes.

One commonly used method to alleviate some of these negative effects created through assessment processes is the adoption of a continuous assessment model (Holmes, 2014). Through the removal of a terminal examination, or at least through the reduction of its weight on overall performance, the pressures perceived by some learners can be

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reduced. There is also comfort in knowing that previous work completed to a perceived high standard is contributing to an overall grade or that future elements of continuous assessment mechanism can reconcile performance perceived to be below a desired standard. Additionally, assessment can be incentivized through the provision of feedback which can positively affect learning gains (Black & Wiliam, 1998) and, if synthesized appropriately into a continuous assessment model, can support student integration into the assessment process further facilitating positive educational outcomes (Nicol & Macfarlane-Dick, 2006). A key goal of the formative process is to advance the learning of the student. Yorke (2003), Orsmond et al. (2000) and Sadler (1998; Sadler 2009), and Black and Wiliam (1998) present the teacher, peers and the student themselves as potential contributors to the formative assessment process and outline the importance of strategic planning for the integration of formative assessment into any learning activity. Black and Wiliam (1998) portray the effectiveness of formative assessment as being dependent on the quality of feedback and the interaction between student and assessor thus highlighting the need for the learner to develop knowledge and skills in the assessment domain. This practice of engaging students with formative assessment cannot be left to chance and therefore learners must be inducted into the process of assessment as learning, developing skills and capacities that are required to be able to function effectively in this space. Failing to recognize this aspect of learning can render even the best teacher/peer feedback as little more than just summative marks or comments on a page. The process of giving and receiving feedback is presented by Nicol & Macfarlane-Dick (2006) and Nicol (2010) as having a significant impact on learners being able to monitor, evaluate and regulate their own learning developing their capacity to make evaluative judgements both about their own and that of others (Boud and Associates, 2010; Sadler, 2009). With the recognition of the positive role assessment can play in the learning process this paper presents an approach to integrating assessment in the CDIO approach in engineering education.

The CDIO Framework for Design in Engineering Education

Not only is the design of an assessment mechanism complex, but it must align appropriately with the evidence that learners create to demonstrate a level of competency. Competencies, broadly defined as an amalgam of cognitive, affective, motivational, volitional, and social dispositions underpinning performance (Shavelson, 2013), are recognized as discipline specific (Zlatkin-Troitschanskaia, Pant, & Coates, 2016) and therefore the context and associated ‘content’ which forms the basis of a learning experience must be thoroughly understood. The context for which an assessment mechanism is presented for in this paper is design in engineering education. Specifically, the CDIO framework as a model for design in engineering education will be discussed.

Crawley, Malmqvist, Östlund and Brodeur (2014, p.1) define the purpose of engineering education as being “to provide the learning required by students to become successful

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engineers – technical expertise, social awareness, and a bias toward innovation". In response to this, they developed the CDIO framework consisting of four stages or activities of the engineering lifecycle which include conceiving, designing, implementing, and operating a design solution (Table 1)

Table 1
Descriptions of CDIO stages (Crawley et al., 2014)

Conceive	Defining customer needs, considering technology, enterprise strategy and regulations, and developing conceptual, technical and business plans
Design	Creating the detailed information description of the design; the plans, drawings and algorithms that describe the system to be implemented
Implement	Transforming the design into the product, process or system, including hardware manufacturing, software coding, testing and validation
Operate	Using the implemented product, process or system to deliver the intended value, including maintaining, evolving, recycling and retiring the system

Under the belief that every graduating engineer should be able to conceive, design, implement and operate complex, value-added, engineering products, processes and systems in a modern, team-based environment, Crawley et al. (2014) designed the CDIO approach with three overall goals: These include educating students who are able to:

1. Master a deeper working knowledge of technical fundamentals
2. Lead in the creation and operation of new products, processes, and systems
3. Understand the importance and strategic impact of research and technological development on society

A critical aspect of the CDIO framework is that despite being designed specifically for the context of engineering education, it is applicable in a broader remit of design education contexts. Arguably, any 'design and make' type task could adopt the CDIO framework, or at least a modified version of it. One of the characteristics of the CDIO framework which makes it so beneficial for engineering design education is the potential that having defined phases affords for assessment practices. As previously discussed, continuous assessment has the potential to alleviate many negative consequences which are created through traditional or terminal assessment practices. It is therefore postulated that incorporating an assessment mechanism which can be used, both validly and reliably, to evaluate the often ill-defined and innovative outputs characteristic of design tasks in education at each stage of the CDIO approach could present a peda-

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gogical model with the potential to positively impact students' learning and educational experiences in engineering education and related disciplines. It is also proposed that the involvement of learners in their own assessment has potential in group situations within the CDIO paradigm where soft skills such as leadership and teamwork can be difficult to identify and evaluate by conventional assessment instruments.

Adaptive Comparative Judgement and CDIO: A Proposed Synthesis

The use of Adaptive Comparative Judgement (ACJ) (Pollitt, 2012b) as a method of assessment has been proven to be both valid and reliable in the assessment of design based competencies (Kimbell, 2012; Pollitt, 2012a, 2012b; Seery & Buckley, 2016; Seery, Canty, & Phelan, 2012, Ryan et al. 2017). Based on Thurstone's (1927) *Law of Comparative Judgement*, assessment is carried out by a group of 'judges' making binary decisions on of quality of work evidenced in multiple pairs of portfolios. From a pedagogical and assessment perspective, the use of students as judges has many advantages. Students have been shown to make judgments on quality which align with those of professional educators (Cheung-Blunden & Khan, 2017). Additionally, by incorporating learners into the assessment process they receive immediate feedback on the quality of their work in comparison to their peers. As this is unarticulated, students must develop self-regulatory skills as well as self-appraisal skills in their interpretations of quality. Finally, the ACJ system prompts judges to give feedback on each portfolio they judge. This request sees learners having to articulate their opinions on quality supporting the formulation of their own constructs of capability and also provides a wealth of peer feedback associated with each portfolio which can be made accessible. In addition to being an assessment tool the ACJ process also has statistical data output that can indicate the degree of consensuality of the judges within the decision making process. The ACJ system can record if a judge is at variance with the other judges within the group. A judge outside of acceptable parameters (set by the teacher/awarding authority) is a cause for concern but can now be identified and an appropriate intervention can be actioned. A similar set of statistics is generated for the portfolios that identify work where there was a significant level of disagreement between the judges. Both of these statistics present the opportunity to analyse where there is and is not consensus providing opportunity for analysis, discussion and intervention for those involved in the CDIO process.

Ultimately, this approach has not yet been explored however there are many foreseeable merits which could be achieved through its incorporation into practice. The current proposal is to integrate ACJ within CDIO by hosting a judging session after each stage of the CDIO framework. These sessions would be externally moderated to identify any potential outliers and to screen peer feedback prior to making it available to students. It is well known that students welcome feedback provided it is appropriate and timely, and that continuous assessment has certain advantages. It is hypothesized that incorporating these elements through the synthesis of ACJ and CDIO will have a positive

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effect of learning. The next stage of this agenda is to pilot this approach in practice as a feasibility study and to refine associated research questions and hypotheses, which will ultimately be result in the generation of empirical evidence associated with learning effect sizes.

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About the Authors

The authors can be contacted at—**Tomás Hyland**, Email: tomas.hyland@ul.ie, **Seamus Gordon**, Email: seamusgordon@ul.ie, **Donal Canty,** Email: donal.canty@ul.ie, **Jeffrey Buckley**, Email: jbuckley@kth.se and **Niall Seery,** Email: nseery@ait.ie.