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

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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 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).

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 "to provide the learning required by students to become successful 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 pedagogical model with the potential to positively impact students' learning and educational experiences in engineering education and related disciplines.

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). 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.

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 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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