BUILDING STUDENT AGENCY THROUGH ONLINE FORMATIVE QUIZZES

Louise Pick, Jonathan Cole

School of Mechanical and Aerospace Engineering, Queen's University Belfast

ABSTRACT

The authors are responsible for a core, first-year module on fluids and thermodynamics for a large class of aerospace, mechanical and product design engineering students. The introduction of a new Virtual Learning Environment (VLE), Canvas, across the university in the 2019/20 academic year, has expanded the potential for active learning and student agency. This paper reports how the curriculum was designed to make use of Canvas features and demonstrates how student engagement was promoted. A key feature of the new curriculum design was a set of formative quizzes spread across the year, each available for a two-week window and with a relatively high pass mark but multiple attempts permitted. No marks were given for the quizzes, but it was necessary to pass them all to be eligible to pass the module. Formative assessments can be an effective strategy to motivate students to build agency, which aligns with section 2.4 of the CDIO syllabus. Quiz 3 was the earliest when not all students passed and two of the three students in question subsequently failed the first summative assessment; this suggests that not only do the quizzes encourage early and consistent engagement with the module, but they also offer the possibility of early identification of students at risk. Evidence of repeated attempts even after a pass mark was achieved suggested a high level of motivation in some students to do well in the quizzes. Student surveys indicated their belief that the quizzes were very helpful. Results from all the summative assessments in the module were significantly improved compared to the previous year, and student satisfaction levels as measured by end of module evaluations were excellent. The outcomes from the redesign have been valuable in informing strategies for the move to effective and engaging online delivery due to the Covid-19 pandemic.

KEYWORDS

Online assessment, quizzes, engagement, student agency, VLE, Standards: 2, 8, 10, 11

INTRODUCTION

Thermodynamics and fluid mechanics modules, frequently taught across a range of engineering disciplines, are often regarded by students as the most challenging subjects in their undergraduate programmes. The challenges in teaching and learning thermodynamics are well documented (Bain et al., 2014; Kesidou & Duit, 1993; Mulop et al., 2012; Rozier & Viennot, 1991; Sokrat et al., 2014; Tatar & Oktay, 2011) and include a lack of prior study at school level, and the conceptual nature of the subject which often leads to a disconnect between theory and practical applications. Similarly, fluid mechanics often has a high level of complexity in the equations presented and therefore requires strong mathematical competency

(Alam et al., 2004). Both subjects build incrementally on previous learning and lectures are usually strongly dependent on previous sessions, meaning that missing a few classes can have profound implications on the ability of students to progress through the course (Rahman, 2017).

Similarly, at Queen's University Belfast, students have historically found the first-year Thermodynamics and Fluid Mechanics module to be very challenging, often leading to poor outcomes on the module; for example, in 2018/19 the failure rate was 30%, with a mean score of 51.2%. Problems arise for the students due to being faced with very new content, taught at the outset of their transition to higher education, coupled with large class numbers, typically in excess of 150 students, which limits the student-instructor contact time. An increase in student agency, defined as "*the capacity to set a goal, reflect and act responsibly to effect change…making responsible decisions and choices*" (OECD, 2019) is required to ensure success (Nieminen & Tuohilampi, 2020). This ties closely into the CDIO syllabus, section 2.4 on attitudes, thoughts and learning, which emphasises the importance of engineers taking initiative, responsibility, working independently, and reflecting on and responding to feedback.

The introduction of Canvas as the new VLE for the university in the 2019/20 academic year gave opportunity to introduce measures to provide digitally-enhanced teaching and learning strategies in the module, and encourage active learning, aligning with CDIO standards 8, 10 and 11 on active learning, teaching and assessment, and encourage the building of student agency (Jääskelä et al., 2020). It was of particular interest to ensure continuous engagement of students with the module, and to encourage students to develop independent and self-motivated study skills.

The Use of Online Continuous Assessment

Several studies have shown clear improvements in outcomes through the introduction of continuous online assessment, particularly through the use of quizzes. Nicol (2007) reported on the effect of online multiple choice question (MCQ) quizzes across a number of disciplines and highlighted that while much focus has been previously placed on the limitations of MCQ in testing higher-order cognitive abilities, they can be used to great effect when linked to a specific goal, for example development of learner self-regulation. This links to a previous study (Nicol & MacFarlane-Dick, 2006) which identified seven principles of good feedback which lead to self-regulated learning and student agency (figure 1).

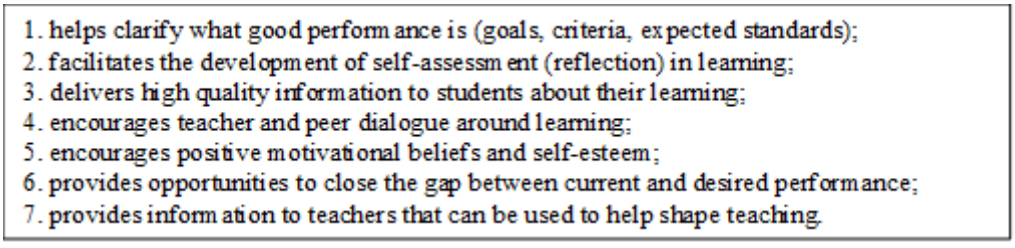
1. helps clarify what good performance is (goals, criteria, expected standards);
2. facilitates the development of self-assessment (reflection) in learning;
3. delivers high quality information to students about their learning;
4. encourages teacher and peer dialogue around learning;
5. encourages positive motivational beliefs and self-esteem;
6. provides opportunities to close the gap between current and desired performance;
7. provides information to teachers that can be used to help shape teaching.

Figure 1: Principles of good feedback practice (Nicol & MacFarlane-Dick, 2006)

Other researchers continue to demonstrate the benefits of online continuous assessment; for example, Orr and Foster (2013) reported on the introduction of "pre-exam" quizzes as part of a biology course. Results showed that students who took the quizzes tended to score higher on the final exams, and that improvements were seen for students of all abilities who engaged

with the quizzes. However, they also reported a significant decrease in completion rate of the quizzes over the course of the module.

Studies by Holmes (2015, 2018) showed that the introduction of low stakes weekly online assessments led to increased engagement with the VLE, and also increased attendance in class. Interestingly, students also reported higher engagement with other module resources, such as increased reading of lecture notes, than in previous years, and the module average increased. Another recent review of methods for online formative assessment demonstrated benefits for students in terms of both module scores and also improved cognitive development (McLaughlin & Yan, 2017). They reviewed the use of quizzes, one-minute papers, e-portfolios and other interactive web-based tools and reported wide ranging benefits across the published studies in terms of final outcomes, engagement, and self-regulation of learning.

The aim of this study was to assess the effect on student engagement and outcomes of the introduction of regular online formative assessment in the first-year thermodynamics and fluid mechanics module in the 2019/20 academic year.

METHODOLOGY

Following a review of the structure and assessment of the module and considering indications in the literature that online quizzes were an effective way of increasing engagement and providing feedback, it was decided to introduce VLE-based formative assessment for the module. This was developed in the form of seven Canvas quizzes spread regularly across the year, each based on the previous 2-3 weeks of lectures. The quizzes were formative and provided no marks, but it was stipulated as a requirement of the module that all quizzes were passed in order for a student to be eligible to pass the module. Due to the issues surrounding the Covid-19 shutdown, and given that the quizzes carried no credit, missed quizzes were waived at the end of the year for the small number of students who failed to complete them all.

Students were given two weeks to complete and achieve a pass mark (generally around 80%) in each quiz, with unlimited attempts. Rather than rely on MCQs alone, the quizzes were set up with a variety of question styles and types to allow assessment of a wide range of levels of learning from simple recall of facts to application of knowledge, to higher analytical skills. Engagement with the quizzes was monitored throughout the year and the outcomes in summative assessments compared with the previous year. Fair comparison over a longer period was difficult due to a relatively large number of staffing and assessment changes in recent years. Some qualitative data was also gathered from students to assess their opinions of the quizzes and the module overall.

RESULTS AND DISCUSSION

Engagement with the quizzes

Table 1 shows that there was excellent student engagement with the quizzes. Quiz 6 showed the lowest percentage pass rate, most likely due to a bunching of submission dates for assignments occurring at that time. Quiz 7 was completed during the first week of the Covid-19 shutdown, and still showed high engagement.

Table 1: Engagement levels with the quizzes

	Module section	Number of students required to take quiz	Number of students who passed	% passed
Quiz 1	Thermo	155	155	100%
Quiz 2	Fluids	155	153	99%
Quiz 3	Thermo	155	151	97%
Quiz 4	Fluids	154	146	95%
Quiz 5	Thermo	153	149	97%
Quiz 6	Fluids	153	134	88%
Quiz 7	Thermo	153	143	93%

Attempts required to pass

Figure 2 shows the number of attempts taken by students to pass the quiz, presented as a cumulative percentage of those attempting the quiz. Quiz 1, given in week 1, was designed to be the easiest quiz and the pass rate was also set lower than subsequent quizzes, at 60%, to ease students into the routine of completing the quizzes. 94% of students passed the quiz on the first attempt and the remaining students passed by attempt 2. Quiz 2, when the pass rate moved to 80%, showed just 40% of students passing on the first attempt, but by attempt 2, 72% of students passed.

Quizzes 2 and 6 showed very similar patterns, with over 90% pass rate by attempt 4. Quizzes 4 and 7 also had similar patterns to each other, in these cases requiring seven attempts for at least 90% of the students to achieve the pass mark. Quiz 5, a quiz on the first law of thermodynamics in closed and open systems, appeared to be the most challenging for students by some distance. It required 13 attempts for at least 90% of the students to reach the pass mark.

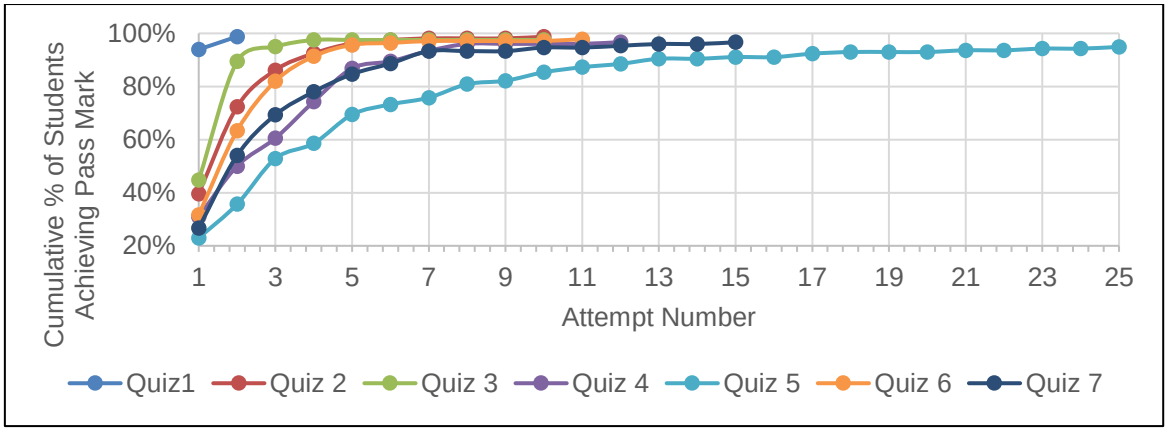

Figure 2: Cumulative percentage of class passing each quiz

Attempts taken by students

The results also showed that many students were motivated to continue to try to improve even after achieving a pass mark, as shown in figure 3. Fifty students took at least one extra attempt to improve their score on quiz 1, dropping to a low of 17 students in quiz 5, which the students found the most difficult. Quiz 3 showed the highest level of students taking two and three extra attempts to improve their marks. The subject of this quiz was an introduction to using the steam tables, often a challenging topic for students initially, so it may be the case that students were practising using the tables. It is difficult to draw full conclusions on the significance of this as there are several variables that need to be further isolated and analysed in future work, including a benchmarking of the difficulty level of each quiz.

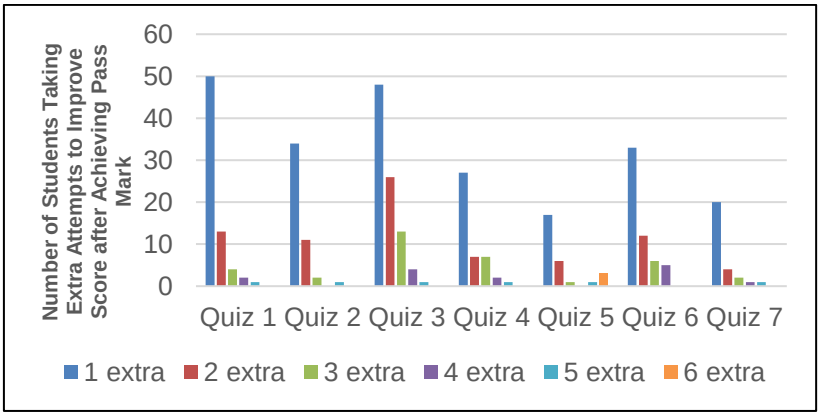

Figure 3: Number of students taking extra attempts to improve score after passing quizzes

Engagement with the Canvas course overall

The quizzes have also increased engagement with the VLE for the module, as seen in figures 4 and 5, showing much higher page views and participation compared with the other core first-year modules. Canvas participation analytics are generated when a student performs an action such as submitting an assignment, writing a discussion post, or taking a quiz.

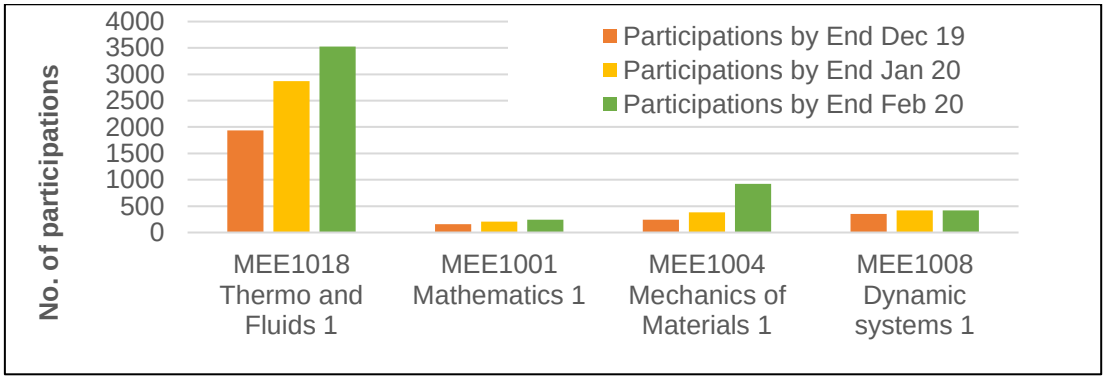

Figure 4: Number of logged “participations” on the first-year Canvas courses

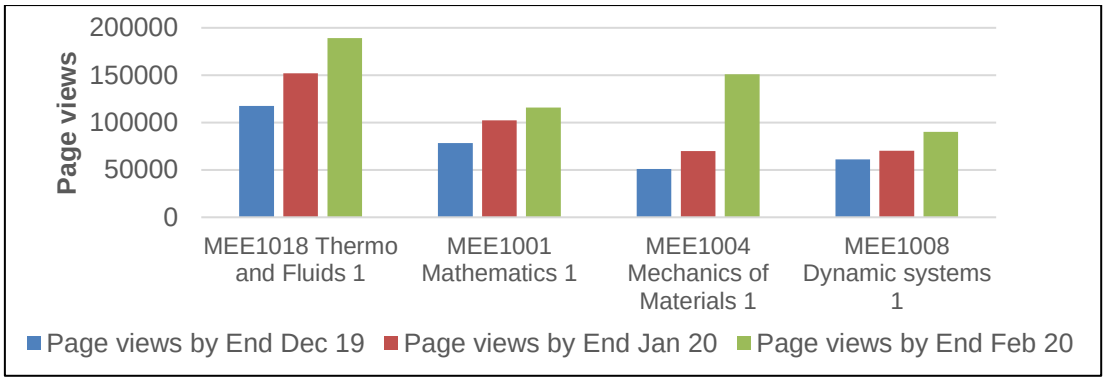

Figure 5: Number of logged "page views" on the first-year Canvas courses

Effect on Summative Assessment

Summative assessment for the module comprised two class tests, one mid-semester 1 and one mid-semester 2, each worth 20% of the module mark, and a final exam worth 60%. The continuous formative quizzes appear to have contributed to improved assessment results. Figures 6 and 7 show the results from students taking each piece of assessment as a first sitting in 2018/19 compared with 2019/20. The averages increased by 16, 11 and 13 percentage points respectively. Two-sample t-tests were carried out to compare the means (table 2), and for each of the three assessments a significant difference was found ($p < 0.001$). It should be noted that the data in table 2 includes results from a small number of students taking each assessment as a resit, which accounts for the discrepancies in student numbers between table 1 and table 2. The percentage of the class who passed each assessment was 20, 25 and 18 percentage points higher respectively.

Caution should be applied before linking improved summative assessment results exclusively to the influence of the quizzes as there was a staffing change on part of the module, and the class tests were not identical in the two years. However, the tests were very similar to the extent that they were of a comparable duration, covered the same range of topics, and were supervised in class in both cases. For the final exam, the Covid-19 shutdown of the university also necessitated an online open-book examination format in 2020. However, the increase in the exam average was in line with the increases in the class tests, so it can be reasonably assumed that the increase on the exam was not solely due to the open-book format in 2020.

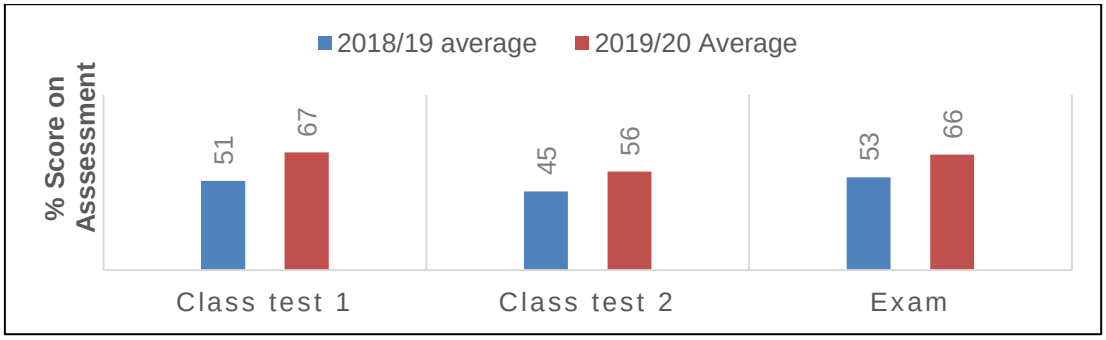

Figure 6: Comparison of average scores in the module's three assessments

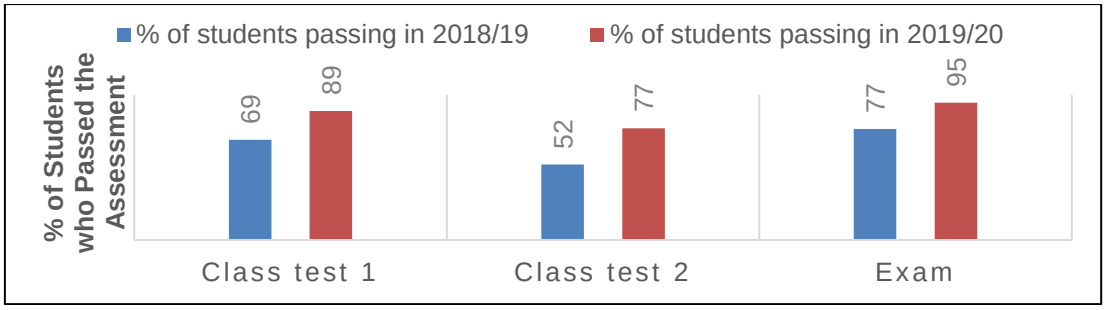

Figure 7: Comparison of percentage of class passing the module's three assessments

Table 2: Comparison of averages for students between 2018/19 and 2019/20 academic years

	2018/19		**2019/20**		**Significant difference in average?**
	Average grade	Number of students	Average grade	Number of students	
Class Test 1	51	158	67	157	Yes, p <0.001
Class Test 2	45	165	56	162	Yes, p <0.001
Exam	53	154	66	158	Yes, p <0.001

Quizzes as a Predictor of Outcomes

The question of whether online formative quizzes and other VLE data can be used to predict outcomes is of great interest. There are numerous studies in the literature which report on student engagement with VLE systems and attempt to link learning analytics with outcomes. Conclusions around these are not always clear and are often contradictory. A review of 252 papers (Viberg et al., 2018) into the effectiveness of using learning analytics found that 35% of the papers showed that learning analytics led to improved learning support and teaching but only 9% provided evidence that student outcomes were improved. More limited value may also be gained from learning analytics in face-to-face courses which are only supported by a VLE, as opposed to fully online courses (Agudo-Peregrina et al., 2014).

In this initial study only a comparison of missed quizzes with outcomes was carried out. It was noted that the first time any students did not complete a quiz was for quiz 3. Out of the three students who did not complete, two failed the first summative class test, held shortly after quiz 3. This suggested at an early stage that quizzes could potentially be used to predict outcomes. At the end of the module the full data was analysed to determine if there was any correlation between missed quizzes and poorer outcomes (table 3). It can be seen that while around 50% of students who failed any of the assessment pieces over the year also missed at least one quiz, it was not always the case that they missed a quiz *before* failing an assessment. It is therefore difficult to determine whether missing a quiz was a predictor of poor performance in an assessment, or if performing poorly in an assessment led to a drop in motivation to engage with the quizzes.

It can however be noted that the average module score for the group of students who missed at least one quiz was 57%; this compares to a module average of 69% for students who passed all quizzes. Much more work is needed to assess the potential for the use of quiz and other VLE data for outcome prediction and early intervention for students at risk.

Table 3: Analysis of the numbers of students failing assessments who also missed quizzes

	Class test 1	**Class test 2**	**Final exam**
Number of students who failed assessment	16	28	7
Number of failing students who missed any quiz	8	15	3
Number of failing students who missed a quiz before the assessment	2	8	3
Number of failing students who missed a quiz after the assessment	5	4	N/A
Number of failing students who missed a quiz BOTH before after the assessment	1	3	N/A

Student feedback

Student surveys were carried out at the midpoint of the module to gather general feedback on the module as a whole. Several positive comments were received about the quizzes, including:

- *"Quizzes were quick and helpful; these should be assigned across all modules in the course in my opinion."*
- *"Online quizzes I think are a great way of just checking up on the knowledge from a module."*
- *"Regular, non-graded quizzes in Thermodynamics and Fluid Mechanics module helps to identify an understanding/ lack of understanding of the content being covered."*

The module evaluation questionnaire completed by students at the end of the year showed an increase in the overall satisfaction score from an average of 4.5 out of 5 in 2018/19 to 4.7 out of 5 in 2019/20.

Implications for Online Learning and Assessment, and Further Work

The Covid-19 pandemic has necessitated a switch to online and/or blended learning and assessment in the academic year 2020/21 for many institutions including Queen's University Belfast. This module, along with some other heavily theory-based modules, which are normally taught over a full academic year, has been condensed into one semester, as they are more easily delivered online under current restrictions than more practical modules which will need to take place face-to-face at a later stage when restrictions are eased. This has led to additional challenges both in teaching and assessment planning for the semester. The positive experiences with the quiz format for formative assessment have encouraged the switch to use of the quizzes for combined formative/summative assessment.

However, there were limitations to the previous study which may have implications for the work in 2020/21. For example, very high average scores obtained in the quizzes in 2019/20 mean that some adjustments must be made when using them for summative assessment. Issues with maintaining the integrity and robustness of online assessments are also clear. Benchmarking the difficulties of each quiz is necessary. An assessment of the appropriate type, extent and format of feedback to students is also needed. Results from the experience in 2020/21 will be reported on in due course.

CONCLUSIONS

The introduction of online formative quizzes in a first-year thermodynamics and fluid mechanics module has shown the following:

1. Almost all students displayed a high level of engagement with the quizzes, with an average of 96% completion rate, even when multiple attempts were required to achieve the pass rate. Many students continued to attempt to increase their score even after a pass mark had been achieved, demonstrating high levels of self-motivation. These behaviours concur with the goals outlined in section 2.4 of the CDIO syllabus on attitudes, thoughts and learning.
2. The introduction of the formative quizzes into the module resulted in significantly more engagement with the VLE compared to the other first-year modules, in line with CDIO standard 8 on active learning.
3. A notable increase in the scores for all three summative assessments was seen, and this was accompanied by an increased percentage of students achieving a pass in each assessment piece.
4. An initial analysis of the potential for quiz data to be used to predict outcomes showed some indication of a link between failure to complete one or more quizzes and poorer outcomes in the module. However much more extensive analysis in the area would be needed to draw firm conclusions on this.
5. Feedback indicates that online quizzes are positively received by students and assist them in self-assessment and self-regulation of their learning.
6. The potential for quizzes to be used as combined formative/summative assessment will be trialed in 2020/21, due to the move to online learning, contributing to CDIO standards 10 and 11.

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BIOGRAPHICAL INFORMATION

Louise Pick is a Lecturer (education) in the School of Mechanical and Aerospace Engineering at Queen's University Belfast. She has current teaching interests in thermodynamics and mathematics and is the VLE champion for the school. She has interests in the use of educational technologies to enhance teaching and learning. Her PhD research was in polymer processing and testing, and she has several years' industrial experience in the area.

Jonathan Cole is a Senior Lecturer (education) in the School of Mechanical and Aerospace Engineering at Queen's University Belfast. He has 17 years of experience teaching mathematics and fluid mechanics to undergraduate students. His interests include mathematics education, assessment and developing students' employability skills. His PhD research involved CFD investigations of arterial blood flow.

Corresponding author

Dr Louise Pick
School of Mechanical and Aerospace Engineering, Queen's University Belfast,
BT9 5AH, United Kingdom
+44 (0)28 90976517
l.pick@qub.ac.uk