Chapter 4

Scenario Assignments within a Digital Platform: A Superior Assessment Tool?

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Abstract

Contact-based tertiary education institutions faced a significant challenge following the onset of the Covid-19 pandemic. Within a short period, both academics and students were required to migrate to an online teaching and learning platform. The results of this rapid change were manifold and revealed deficiencies that were endemic in many programmes. Conventional tests were still testing at low cognitive levels; plagiarism and collusion in online assessments were rife; and the type of assessments offered created an enabling environment for this. There was also often poor alignment between the course content and assessments, and no tangible use of taxonomies. Within the context of these challenges, two assessment tools were interrogated (viz. conventional tests and scenario assignments) to determine and compare their effectiveness in the learning cycle, characterize the possible extent of collusion in the digital space, and consider the inclusivity of the assessments for variably-resourced students. The experiential study looked at a cohort of 100 students at the third- and fourth-year levels of a professional degree, and at sequential modules that are linked in content and learning outcomes. Scenario assignments, especially within a digital platform, offered the lecturer the opportunity to better assess the students' skills and knowledge of practical application, troubleshooting, optimization and design. These are all particularly important for professional practice. By setting up the scenario with open-ended elements, there was sufficient novelty required in each student submission to deter plagiarism. However, the informal student network and peer-to-peer interaction were also strengthened, which could be valuable from a social perspective. The lack of

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access to literature resources, or student motivation to carry out more than a superficial search for such resources, does impact on the overall performance in these assessments. The use of scenario assignments should therefore be carefully balanced against the available notional hours and resources of the students.

Keywords: Scenario assignments, continuous assessment, engineering education, problem solving, open-ended

1 Introduction

Higher education in South Africa, and in fact globally, experienced an unprecedented change during 2020 and 2021, having to migrate quite rapidly to an online mode of teaching and assessment. In many respects it was a disruption of the status quo. Without physical contact lecturers needed to think more creatively about how to engage students in the learning process and how to assess our learning outcomes adequately. From a teaching perspective there are two major things that the Covid-19 pandemic did. Firstly, it accelerated the digital transformation of tertiary education at traditional universities, and secondly, it made necessary the interrogation of current teaching practices. Lecturers needed to reflect on how modules were being taught and whether the existing structure was adequate, even under normal circumstances. Hence there was also a migration away from the conventional LTTE (or lecture, tutorials, tests and exams) approach to the use of multiple and different types of assessment within a continuous assessment framework.

In engineering education, a major criticism of graduates is the lack of problem-solving skills, as well as a lack of flexibility in practice and the ability to cope with ambiguity in the workplace (Wellington et al. 2002). Moreover, there is a strong assertion amongst industry practitioners that examinations do not provide a meaningful measure of real-world skills that graduates are expected to demonstrate in the workplace (Wellington et al. 2002). There also appears to be a deficiency in the way students approach learning within a programme.

Consider the following analogy. Suppose that there is a man on a raft in the middle of the ocean and he comes across a deserted island. He finds on the island various resources, but also detailed instructions on how to build a shelter, gather and prepare food. He survives there for a while and then moves on to the next island where, lucky enough, he finds similar resources easily at hand along with detailed instructions. After repeating this several times, the man arrives at an island completely unfamiliar to him, with resources not so plainly in sight and no instructions. The man struggles to survive.

Students within engineering programmes and even within individual modules are learning and being assessed on 'islands', and hence find it difficult to apply themselves in unfamiliar situations or to a different problem. Instead of allowing students to learn recipes to solve a specific problem or counter a specific situation, we should provide them with the tools and knowledge to navigate the complex challenges that they will face in the workplace. By placing the learning in an authentic and holistic context, students are better prepared to solve ill-structured, emergent problems that are common in the real world (Jonassen, Strobel & Lee 2006). The use of scenario assignments as an assessment tool may be a means to do this. In this chapter we explore the use of scenario assignments within the context of a final-year module of a four-year professional engineering degree. We consider the modalities for developing and assessing such an assignment, as well as the operational challenges that can have an impact on the students' performance.

2 Theoretical Framework and Literature Review

Engineers in professional practice solve problems through a structured approach. They frame the problem, collect the necessary information, propose a solution based on established theory and practice, and articulate the solution through oral or written means. One of the most desired qualities amongst graduate engineers is the ability to transfer the knowledge gained during undergraduate training to a workplace context, and to solve real-world problems (Mohd-Yusof, Phang & Helmi 2014).

The teaching of the more fundamental concepts in engineering can be achieved, e.g. through the use of shaping to break down information into smaller steps, monitoring the performance of the learner through tutorial engagement, interviews and short tests, continuously intervening with feedback and reinforcement (Aronson & Briggs 1983). Students can also be assigned specific objectives and allowed to practise until mastered. The latter is often assessed through a summative examination. One should also be aware of the internal models that students create and curate during this process, and that these models are the basis for knowledge assimilation and application at higher levels (Tobias 2010). Problem solving, however, is a complex skill that requires a level of critical and creative thinking and the ability to carry out self-directed learning (Mohd-Yusof et al. 2014). In order to inculcate such a skill properly, the students' previous knowledge needs to be activated and challenged to enhance the complex networks of associations within their minds. The organization of these associations leads to learning with understanding, rather than a superficial knowledge of surface features. Students have to harness a complete cognitive system integrating both internal and external factors (Hutchins 1995). Such a system of distributed cognition would then benefit from a form of situational instruction, embedding the learning in becoming a participant within a community of practice (Lave & Wenger 1991).

Problem-based, or within the engineering context, design-based learning, is a blended cognitive-situative approach (Von Glasersfeld 1989), where the lecturer presents students with design problems upfront to work on, then delivers content that supports discovery and problem solving, playing the role of a facilitator or design consultant. It is an example of active learning, which includes the process of inquiry and knowledge seeking, where students actively investigate and construct solutions to design problems (Gómez Puente & Jansen 2017). The learning approach is supported by a distinct assessment strategy, which is often based on scenario assignments. Scenario assignments have been used to assess various engineering competencies, including problem solving (Daniel & Mazzurco 2019). It is usually comprised of three key elements, i.e. a scenario, a set of questions to guide the inquiry or design, and a scoring system to aid in the assessment (McKenna 2007). The scenario must represent a realistic situation, and the questions are usually open-ended so as to encourage self-directed inquiry, consultation and even debate. In terms of the scoring system, the development of a satisfactory rubric is very important and would often involve at least one independent moderator, to ensure that there is no bias in coding and assessing the students' responses (Daniel & Mazzurco 2019). In fact, the development of the rubric is usually an iterative process involving the lecturer and moderator. The assessment itself can take the form of a report, a series of quizzes, or a presentation (Gómez Puente et al. 2015). Problem and design-based learning typically includes an element of constructive social interaction, i.e. cooperation amongst students to formulate a satisfactory solution to the open-ended design problem (Gómez Puente & Jansen 2017). In most cases, therefore, scenario assignments are undertaken by a group of students rather than an individual.

The global shift to online learning during the Covid-19 pandemic necessitated a thorough interrogation of current teaching practices, including assessment. The conventional methods, which include tests and examinations, where found to be inadequate given the propensity for collusion. In this study we investigate the use of scenario assignments as the exclusive assessment tool for an applied engineering course, and consider the efficacy of the approach in determining individual student competencies, but also the development of problem-solving skills.

3 Methods

The learning outcomes of most engineering education programmes fall under two broad categories: a) engineering knowledge and problem solving and b) engineering professional skills (Brophy *et al*. 2008). The latter encompasses the soft skills such as technical communication, individual, team and multidisciplinary working, as well as engineering professionalism and management. These are complemented by those in the first category, which include solving complex problems, design, investigations and analysis, as well as the general use of engineering skills and tools. Engineers apply disciplinary concepts (such as the laws of mass, heat and momentum conservation, as well as aspects of thermodynamics, amongst others) to comprehend how systems work, and offer solutions to problems. They have to shift rapidly between two dimensions of problem solving: a) simple problems that can be solved rapidly and efficiently and b) complex problems that require the use of previous knowledge to activate a structured search for new knowledge and identify possible solutions (Schwartz, Bransford & Sears 2005). Activating and developing the latter at the undergraduate level are a challenge. Scenario assignments can be used to good effect in this sense.

Scenario assignments are not a new assessment tool; in fact, it has been used effectively in the past in medical education, for allowing students to gain skills in diagnosis, exploration and testing (McMartin, McKenna & Youssefi 2000). It has also been used in engineering education, particularly in the area of engineering ethics and even engineering design. The scenario assignment is designed for students to respond to an open-ended problem, set within an authentic context and probing an issue of engineering importance. It draws on students' critical thinking skills, problem formulation and management of resources and expertise, and is inspired by situated cognition theories of learning (McMartin *et al*. 2000).

We piloted the use of scenario assignments as the exclusive assessment tool within the final-year module ENCH4RT Applied Reactor Technology. This was a suitable choice, as it leads on to the capstone design course and has a direct link in terms of content and learning outcomes to a third-year course in reactor technology fundamentals, ENCH3RT. The latter uses tests as the primary assessment tool. Since the cohort of approximately 100 students had undertaken both courses during the online teaching programme, it offered the opportunity to analyse and compare their performance using two different assessment strategies. Table 1 summarizes the learning outcomes of the two modules.

Table 1: Summarized learning outcomes for pilot modules

ENCH3RT	ENCH4RT
Demonstrate the ability to understand and calculate reaction rates, yields and compositions in well-defined chemical reaction systems	Demonstrate the ability to design and optimize complex chemical reactors

During the first semester of 2021, the scenario-based assignments were administered to a total of 114 students enrolled in ENCH4RT, of which 104 participated in the ENCH3RT module the previous semester and form the basis for this study. The students were provided with a module outline which indicated the type and weighting of the assessments, as well as the module and assessment outcomes. The students were given a problem statement, which provided some context for the scenario, partially defining the problem and finally some guidance on what was required, i.e. the students' task. Figure 1 shows a sample scenario used as the basis for one of the assignments. In this example, the students are briefed on a specific reactor configuration and a problem that have been encountered. The specifics of this problem have been drawn out of an authentic industrial case study. The issues have been broken down into various sub-parts to assist in the discovery of the overall solution.

The ENCH4RT module is further based on a case study approach. Each fortnight a different reactor configuration is interrogated through a series of lectures, readings and video exercises (watching online content related to the topic), all grounded in a particular case study of an industrially relevant process. This is book-ended by open discussions on the topic and calculation examples illustrated in class. By making use of a blended approach we are able to centre the learning on the student and facilitate guided inquiry that ultimately leads to a better understanding of the design process. The students are given the open-ended design problem (the scenario) upfront and are encouraged to discuss, interrogate, brain-storm and share thoughts on the solution. Unlike conventional, problem-based learning pioneered at McMaster and Maastricht Universities (Beddoes, Jesiek & Borrego 2010), each student that participates in the ad hoc group eventually has to propose a unique solution to the problem; therefore, although they collaborate, they are also constructing and being assessed on their own knowledge.

Problem statement

You are a process engineer employed at a bulk chemicals facility. The gas-phase partial oxidation of a particular hydrocarbon intermediate is carried out in a multi-tubular fixed bed reactor, using a new metal oxide catalyst supported on bentonite clay (which has replaced the older catalyst that was supported on alumina). The reaction is highly exothermic and practically irreversible. The total oxidation route is also possible, but only under very high temperatures. Coolant is fed co-currently on the shell side, with the catalyst packed into the tubes. Under the prevailing conditions, the reaction is known to be affected by both external and internal mass transfer resistances. The reactor is fully fabricated from carbon steel and equipped with an array of axial temperature probes to monitor the process gas temperature and hot-spots. The reactor operates close to atmospheric pressure. There are no radial gradients of temperature or composition within the reactor tubes under normal operation.

After several months on stream the operations team notices a problem. The performance of the reactor is not within the specified parameters. The senior engineer suspects that there are blockages on a portion of the reactor tubes. Further investigations show that as much as 25% of the tube bank is affected.

Assessment Details

This assessment must be completed as an individual task. The assessment is due at 16:00 on 28th May 2021. Your report is strictly limited to three pages (inclusive of all equations, diagrams and references). An assignment submission portal will be set up on the course Moodle page, please make sure to submit your assignment before the deadline.

Your Task

Part A (5 Marks)

List and discuss possible causes for the blockage on the portion of the reactor tubes and indicate how these causes could be verified.

Part B (12.5 Marks)

List and discuss the effect that the blockage will have on the performance of the reactor (e.g. composition and temperature profiles, etc.)

Part C (7.5 Marks)

Propose a method to improve the performance of the reactor temporarily, without taking the unit off-line.

You may show any necessary equations to support your discussion. If you do, you only need to provide a symbolic solution, no actual numerical calculations or simulations are required. State any assumptions made. You must fully discuss each point, and provide necessary justifications.

Figure 1: Sample scenario assignment

Assessment of the students' performance in the assignments was based on a comprehensive marking scheme and marking memorandum. The latter explored each possible solution, but with flexibility to allow for different options from the students. Here the lecturers experience is very important, since he/she should be able to pick up false logic and impractical solutions from the students, but also any specific ideas that are valuable from a practical or industrial perspective. Figure 2 shows an extract from a marking memorandum.

Marking Memo

Part A

- We first note that the catalyst has been changed from the relatively stable alumina-supported catalyst to one supported on bentonite clay. The clay support is unlikely to be resistant to attrition and it is possible that the catalyst was crushed and compacted during operation, resulting in a blockage in several of the reactor tubes. There would be catalyst residue in the effluent piping, which could be isolated and checked. The engineer / original designer should have done some research on the new catalyst prior to installation. There should be expected life-spans and runtimes associated with it from the manufacturer and datasheets available, in order to compare the operation. Maybe it is known that after 3 months new catalyst is needed. It would also be prudent to call in the catalyst supplier to explain why their catalyst performance has started to drop and they must account for their product.

(2 marks)

- Oxidation reactions are prone to catalyst deactivation by both sintering and coking. Compromised catalyst integrity and excessing coking could have also resulted in blockages, but this would have also been picked up early with a corresponding decrease in performance and selectivity.

(1 mark)

- The reactor is fabricated from carbon steel, which is prone to corrosion when exposed to specific chemical compounds. Corroded tubes could have collapsed and resulted in no-flow through a portion of the tube bank. It would be difficult to verify, however the surrounding piping could be isolated and checked for any excessive corrosion. If there has been corrosion, it often occurs on the welds, and on the tube sheet, and minor cracks from stresses e.g. heating/cooling too fast. This would also result in leakage form shell to tubes, or the other way depending on which pressure is highest, which means either the coolant or the product becomes contaminated. Both fluids can be checked for the contamination. Mild steel is also quite ductile, so it can warp out of shape quite easily at high temperatures (>500 °C) if there is a temperature gradient and not well supported.

(2 marks)

Figure 2: Sample marking memorandum

The students were given a comprehensive feedback sheet, with comments on the various solutions posed for each scenario. A sample of the comments for the top 10% and bottom 10% of the student scores are presented below.

Bottom 10%, representative feedback

- Flow in the packed bed unlikely to lead to catalyst redistribution, unless there is breakage and dusting of the catalyst.
- The sticky product that is referred to could be a heavy by-product; this is an interesting point.
- The blockage actually causes a high-velocity condition in the remaining tubes, resulting in low residence time, conversion, rate and heat generation, and hence a flatter temperature profile.
- Coolant blockages are not the issue in this system; the blockages exist on the process side.
- The discussion on part A is inadequate. The first paragraph speaks of the normal operation of a multi-tubular reactor system, and only a brief (and partial) list of causes is given. These should be discussed. Only some, like the process operating conditions, are valid.

Top 10%, representative feedback

- Consideration of effects is excellent, vary in depth and supported by a variety of literature evidence. It appears that some basic simulation work was carried out to determine the effect on temperature and pressure profiles, well above what was required for this question, but very much appreciated.
- Discussion of the effect of the blockages on performance is particularly good, there is a great logical development of the argument. Flowrate related to velocity, related to pressure drop, rate, conversion and yield
- Some interesting proposals for restoring performance focused mainly on the blockages. However, could have considered the process as well. The obvious one is process feed temperature.
- The analysis of the effect on performance is good, but focused a lot on the blocked tubes (which really would have no flow). On the unaffected tubes the increase flowrate and pressure drop have some interesting consequences for performance.

These feedback not only serve as a means to guide the assessment of individual achievement of competency, but also to assist student learning beyond the module.

3 Results

The results of the study are in three parts, viz. external and independent professional opinion, student feedback and student performance. Given the relatively short timeframe, there are concise but nevertheless valuable.

The assessments were subjected to independent moderation by a professional engineer with 15 years' experience in the field. His comments were overall favourable. In particular he pointed out that the student 'had to make critical thinking decisions about how to find the information required for the problem'. Moreover, he said that the 'open-ended assessments gave students the opportunity to show engineering skills such as solving complex problems with many parameters'. The assignments also 'allowed students to demonstrate both technical knowledge and engineering trade-offs, which are common in industry'. Student feedback, although limited, was also positive, with some commenting that the scenario assignments were beneficial and well-received, and that authentic learning had taken place.

The final-year modules in the chemical engineering programme generally have high pass rates, and 2021 was no exception, with over 90% of the students obtaining a pass on the ENCH4RT module. When comparing the difference in scores that the students' achieved against those in other professional modules during the semester (cf. Figure 3 and Figure 4), one can see that in general the student performance was better (only 47 of the original 114 students participated in these other professional modules during the same period). However, there are a number of factors that affect these performances, including the prerequisite knowledge and the type and weighting of assessments used in the other modules, let alone the fact that these are delivered by other academic staff with unique capabilities and teaching styles. This makes direct comparison difficult. It was therefore decided to interrogate the students' performance in ENCH4RT relative to the third-year ENCH3RT module. Both of these modules had been delivered by the same lecturer. Figure 5 shows the relative difference in scores between these two modules. Interestingly, the majority of students scored higher in ENCH3RT, but evidently did not carry over the knowledge gained in that module effectively to the fourth-year module. This may be an indictment of the effectiveness of the test platform used in ENCH3RT in assessing the learning outcomes of these students.

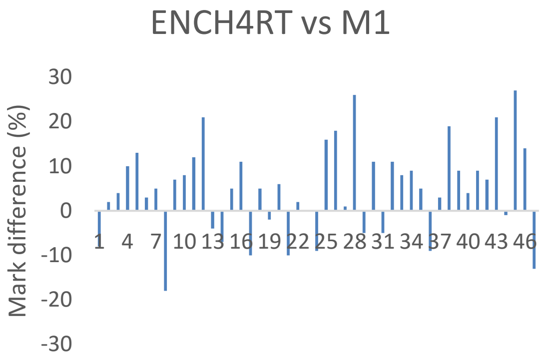

Figure 3: Comparison between student performance in ENCH4RT and contemporary 8 credit exit level module – sample of cohort

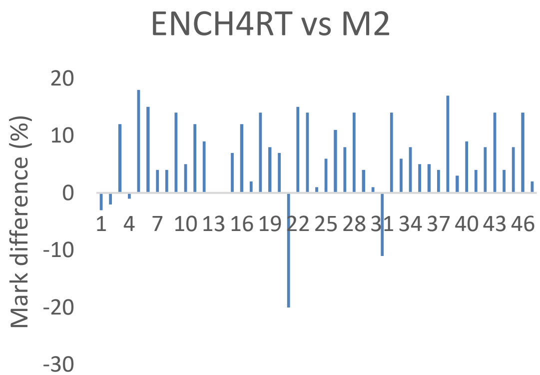

Figure 4: Comparison between student performance in ENCH4RT and contemporary 16 credit module – sample of cohort

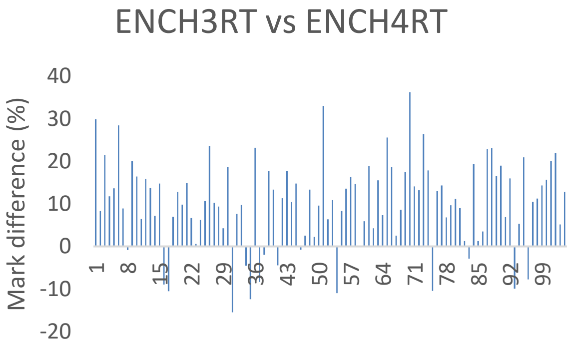

Figure 5: Comparison between student performance in ENCH3RT and ENCH4RT – full cohort

The scores obtained in ENCH3RT and ENCH4RT were further compared against the weighted averages for the degree (cf. Figures 6 and 7). The median value for ENCH3RT was 15% above the weighted average for the degree, whilst the median value for ENCH4RT was 5% above. Comparing these values to the increase in the weighted average over the second semester of 2020 and the first semester of 2021 for the same cohort of students (cf. Figures 8 and 9), it is clear that the student performance in ENCH4RT was more consistent with the student performance over the degree and hence may be a clearer reflection of the students' ability. The results shown in Figures 8 and 9 also reveal an important trend, i.e. students are faring better in their studies during the online programme. It is still unclear whether this is through improved pedagogy or an inflation in performance due to the lack of it. To answer this question would require more data and analysis and is beyond the scope of the present work.

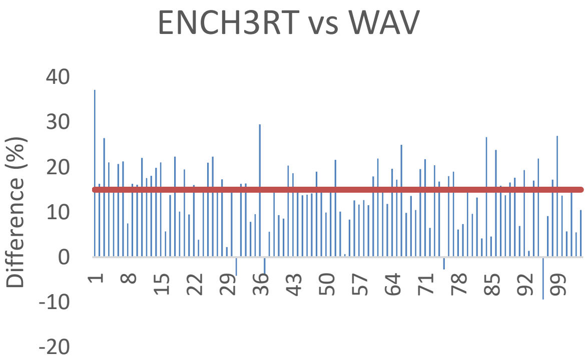

Figure 6: Comparison between student performance in ENCH3RT and weighted average for degree – full cohort (Median = 15%)

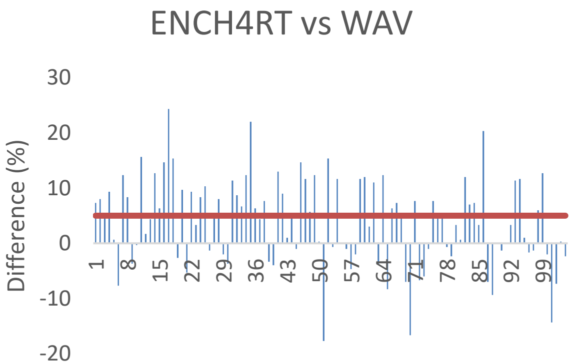

Figure 7: Comparison between student performance in ENCH4RT and weighted average for degree – full cohort (Median = 5%)

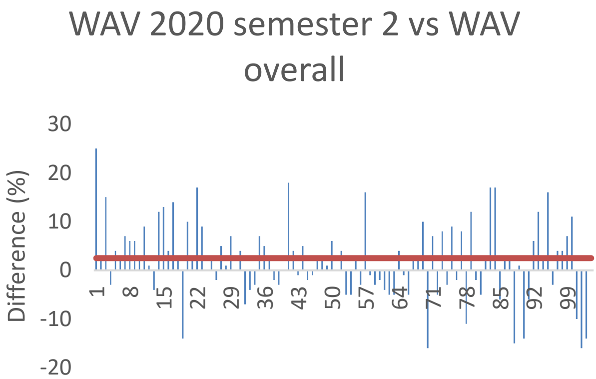

Figure 8: Comparison between student weighted average in Semester 2 (2020) versus weighted average for degree – full cohort (Median = 2.5%)

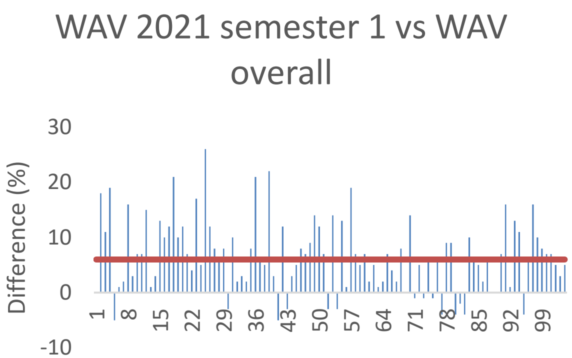

Figure 9: Comparison between student weighted average in Semester 1 (2021) versus weighted average for degree – full cohort (Median = 6%)

As is usual when introducing a new teaching or assessment tool into a programme, there are operational issues that also need to be considered. By their very nature, open-ended problems require of students to look beyond the obvious, beyond the notes and tutorials, and for them to probe the literature to discover new information that could help them in finding a solution. The students' ability to access literature resources has a direct impact on their performance in the assessment. What we also find is that students are often unmotivated to extend their search for information beyond a superficial attempt, and this is something that needs to be encouraged when using scenario assignments.

The constraints on library resources at the institution should be kept in mind when designing the assessments. There has been a recent push towards open-access publishing, with a number of journal and book publishers allowing partial or full access to their content, and full advantage should be taken of this. In the offering of the ENCH4RT module, a peer-to-peer support programme was implemented, incentivizing the uploading of papers and technical reports as well as class summaries that the students were willing to share. Where possible, some literature was made available to students to explore. In this way the students had equitable access to a body of resources that could support their learning. In practice the lecturer should command some oversight on the material uploaded on the Learning Management System, to ensure that only valid information is made available to the cohort.

One of the key aspects to consider when introducing new assessments are the notional hours for the course. Self-study and assessment time should provide adequately for the students to undertake the necessary research and reading, and to summarize the solution in the form of a report. When using scenario assignments as the assessment tool, it is not necessary to ask the student to provide a lengthy document padded with an extensive literature review. In the ENCH4RT module the report length was limited to three pages. The task thus also provided the students with the opportunity to write concisely and with relevance, something that seems to be a challenge amongst engineering graduates, but also a valuable skill.

4 Discussion

Comparisons to Literature and Conventional Assessment Methods

Considering the three key elements of scenario assignments (Mckenna 2007), we have found that for successful use of the assessment tool for the applied engineeering course in this case study, all three play a critical role. Although there is a wealth of different scenarios to choose from, these should be regulated according to the educational value and the authenticity they impart to the problem. Students were better engaged in ‘feed-forward’ design problems, rather than ‘feedback’ operational troubleshooting problems. This could be as a consequence of the recipe-based approaches that the students were exposed to in developmental modules. In fact, the use of problem-based learning techniques can be challenging when students are surrounded by modules using the typical lecture and assessment approach (Mohd-Yusof et al. 2014).

The open-endedness of the problem has to be carefully aligned against the resources that the students have available. This is congruent with the observations of Gómez Puente et al. (2015). The student discovery process may need to be partially supervised/guided as well, since the students can easily lose focus on the problem.

Implications for Other Engineering Modules in the Curriculum

The scenario assignment can be used as the sole assessment method within a higher-level engineering module, demonstrated most effectively when there are engineering design and operability elements in the problem. It remains to be seen how these assignments can be used effectively at the entry and developmental levels of the programme, where methods such as concept testing may prove more beneficial.

Critique and Future Research

Although we believe that the sample size was appropriate for interrogating the use of this assessment technique for the remote teaching period, it is small to make generalized conclusions. The data collected over several years may further confirm existing trends.

Open-ended problems naturally invite a variety of responses, and there exists the potential to receive responses that are not adequately covered by the existing rubric. It may therefore be necessary to use lecturer, moderator and student response input iteratively to finalize the scoring system for these assessments.

We aim to track the progress of the graduates that have participated in these modules to monitor how the training has translated into real world practice, using interviews within the three years post-graduation. The analysis would nevertheless be subjective and would depend on the self-assessment of the individual.

5 Conclusion

At this point it is probably worthwhile addressing the titular question of this paper. Are scenario assignments a superior assessment tool within an online framework? It is probably too early to say conclusively. There are also ways to improve the validity of online testing, such as the use of extensive question banks and online proctoring. The pilot study conducted and presented here shows that scenario assignments can be used as an acceptable alternative to conventional tests, especially when assessing the students' ability to apply critical thinking and solve complex problems, and may actually offer a better means of assessing the students' true ability with regard to the second dimension of problem solving. Within an online teaching platform, and with properly designed assessments considering the student resources and time, they allow the lecturer to probe the students' skills and knowledge. Hopefully, as we all transition to a new form of blended teaching in the future, we will be able to embrace the various options for assessment and in this way take full advantage of the provisions that digital platforms in higher education have made possible.

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