Use of DMAIC methodology to enhance online delivery and assessment during and beyond the COVID-19 pandemic

Mendon Dewa   Department of Industrial Engineering, Durban   mendond@dut.ac.za
                         University of Technology, Durban, South Africa

ABSTRACT

COVID-19 prompted a radical shift in many universities globally, from contact lectures to adoption of online learning and assessment. A university of technology in South Africa has similarly undergone this transition of adopting an online learning and assessment platform. However, there have been many challenges faced in ensuring integrity of online assessments and ensuring that learning outcomes are addressed. This study aims to investigate the factors that inhibit reliability and effectiveness of online assessment during and beyond the COVID-19 pandemic in a department of industrial engineering at a university of technology in South Africa. The study sample consisted of 80 third-year students enrolled in a Production Engineering course. A five-stage Define-Measure-Analyze-Improve-Control (DMAIC) methodology was used to identify the factors that influenced the reliability and effectiveness of online assessment and, thereafter, to improve the online assessment process. The results demonstrate that there was room for improvement in the online learning environment, which in turn led to more authentic assessment and better academic performance by the students. Recommendations are made regarding strategies that could enhance the integrity of online assessments and minimise cheating while ensuring that learning outcomes are addressed.

Introduction

Globally, despite strict measures being adopted by many countries, COVID-19 prompted a radical shift in many universities, from contact lectures to adoption of online learning and assessment (Dhawan, 2020). Online formative assessments, through platforms such as Moodle and Blackboard may give students greater responsibility for their learning and better reflect the nature of online learning. These formative online assessments enable students to demonstrate their capabilities in solving problems and critical thinking, and these are key strengths required when shifting from traditional teaching to e-learning (Liang and Creasy, 2004). Considering the growth in information technology, there is also growing certainty that online learning and assessment will persist post-COVID-19 pandemic.

Academic integrity and student assessment are indispensable in higher education and it is one of the key challenges faced by lecturers, particularly when students are not physically in the lecture room. A University of Technology (UoT) in South Africa has similarly undergone a transition from contact lectures and assessments, adopting online learning and assessment due to the COVID-19 pandemic. However, lecturers face many challenges in ensuring the integrity of online assessments while also ensuring that learning outcomes are addressed. The Define-Measure-Analyze-Improve-Control (DMAIC) methodology was deployed to solve administrative problems in higher education; however, there is a lack of research describing how DMAIC might be used to improve online academic assessment processes. The present study aims to investigate the factors that inhibit the reliability and effectiveness of online assessment during the COVID-19 pandemic at a department of industrial engineering at a UoT, and provide recommendations to improve the online academic assessment process beyond the pandemic.

Literature review

Online delivery and assessment

Universities across the world have resorted to online teaching, learning and assessment as a result of the need for physical distancing due to the COVID-19 pandemic (Oliveira, Grenha Teixeira, Torres & Morais, 2021). The current educational landscape for online assessment is characterised by the use of learning management systems; however, the ease of use and functionality differ considerably between these systems. Examples of these learning management systems include WebCT, TRIADS,

CompAssess, and Discourse. In higher education, online formative assessment has emerged as being focused on four key components: authenticity of the assessment activities, learner support, effective formative feedback, and multidimensional perspectives (McLaughlin & Yan, 2017).

WebCT, now known as Blackboard, is a software application that is designed for a virtual learning environment to generate questions at random from the database and straightforward computer-based assessments can be created (Campus, 2003). Students can be provided with weekly practice problems such as true/false, multiple-choice, and matching questions and are immediately provided with the correct answers after submission of their answers. On the other hand, TRIADS is a widely utilized system that allows the instructor to create a collection of question styles. The instructor can create up to 40 different types of interactive questions that include drawing figures, manipulating objects and labelling diagrams. After each assessment, feedback is provided to the user such as identifying correct and incorrect sections of a problem, as well as guidance on accessing additional information concerning the relevant content (McLaughlin & Yan, 2017).

Customised assessments can also be provided to students through CompAssess which uses all Microsoft-based programs such as Word, Access, Excel and PowerPoint. In South Africa, Brink and Lautenbach (2011) conducted a study on implementation of CompAssess and the language that was used for questions was perceived as too difficult by faculty, while the student survey revealed that the language used in the interface was clear. However, despite the benefits of offering a platform for more practice by the students, qualitative findings revealed that instructors were unable to import assessments across multiple campuses through the CompAssess system (Brink & Lautenbach, 2011). Despite the advent of the COVID-19 crisis, research in Zimbabwe shows that although teaching and learning in institutions of higher learning and schools has been negatively affected, it has also been transformed, triggering a learning revolution through online models such as video conference platforms, Google Classroom, Email, and WhatsApp, among other modes of e-learning (Sibanda & Muyambo, 2020).

Academic integrity

Academic integrity is an interdisciplinary concept that evokes strong emotions in instructors, students and researchers, and the discussion tends to revolve around the prevention of behaviours such as plagiarism, cheating, fraud, dishonesty and other academic malpractice (Bertram Gallant, 2017). Focusing on the promotion of positive values of academic integrity such as trust, honesty,

fairness, responsibility, respect, and courage is a more productive approach that can drive ethical academic practice. In the United States, where higher education providers enjoy a high degree of autonomy, the academic integrity movement was based on British Higher education models that were aimed at addressing moral and ethical issues (Fishman, 2016). Australia also advocates for the supremacy of institutional autonomy as the topmost priority concerning academic integrity and the governing legislation requires educational institutions to maintain academic integrity (Gamage, Silva & Gunawardhana, 2020).

However, it was noted that international students, especially from China, were reportedly less accustomed to academic integrity practices in Australian universities. Bretag, Mahmud, Wallace, Walker, James, Green, East, McGowan and Patridge (2011) describe academic integrity as being multi-dimensional, necessitating combined effort from instructors, students, advisors, librarians, research colleagues and administrators. In South Africa, student cheating and plagiarism have become issues of concern as well, especially when large classes are being taught. Mahabeer and Pirtheepal (2019) conducted a study on assessment, plagiarism and its effect on academic integrity. It was found that the quality of teaching, learning and assessment is compromised by the growing problem of academic dishonesty, especially in large class sizes as a result of the 'massification' of higher education. The problem of 'massification' whereby universities are characterised by high student enrolment imposes intolerable demands on existing physical, human and financial resources.

Assessment security

While academic integrity is aimed at equipping students with the values and competences that are crucial for engaging in ethical scholarship, the focus of assessment security is securing assessment against cheating, and being able to detect any student cheating occurrences (Khan, Hill & Foltýnek, 2020). Both assessment security and academic integrity are vital to ensure that university graduates have fulfilled all the prerequisite learning outcomes. One way to mitigate threats to assessment security is to design assessment methods that are robust enough to withstand challenges of contract cheating. In this sense, learning productivity is enhanced while concurrently developing essential graduate attributes in students. Manoharan and Speidel (2020) reported a case study on investigating how students who were given computer science assignments used a specific online tutoring organisation to purchase solutions. The results demonstrated that purchasing solutions for homework questions was cheap and easy and the questions were neither flagged nor identified as

violations of academic integrity. It was concluded from the study that no single approach is fool proof, given the complex nature of contract cheating; hence, a multi-faceted approach that combines several potential solutions could be used to tackle contract cheating. One promising solution in the engineering domain was proposed, which is to give students individual assignments with assignment fingerprinting. Another basic principle in assessment design is to ensure that students demonstrate their learning practically. On the other hand, formal written examinations may reduce contract cheating; however, they might not be able to accommodate assessment of all types of learning (Dawson, 2020).

Assessment security has been maintained through adherence to deadlines and it was perceived that controlling or limiting the time available to complete assignments would avoid cheating. However, there is cumulative research evidence that demonstrates that deadlines are no longer barriers to student cheating (Gamage *et al*, 2020). It is worth noting that assessment restrictions are harder to enforce remotely and thus, there is a greater probability of cheating during online assessments by students when compared to campus-based students (Vegendla & Sindre, 2019). Remote online teaching is devoid of assessment restrictions such as invigilation of examinations, quizzes and presentations, and students may use other sources and seek support from freelancers or friends to answer questions.

DMAIC

Design-Measure-Analyze-Improve-Control (DMAIC) is a structured problem-solving method that uses data for process improvement (Shankar, 2009). Generally, when implementing DMAIC as a process improvement framework, one commences with problem definition (D) and then measures the present output of a process (M), after which follows analysis of results (A), instituting corrective action (I), and then control over the process to curtail variations in future (C) (Carnovale, Allen, Pullman & Wong, 2016).

Sarda, Bonde and Kallurkar (2006) conducted a study on the application of DMAIC in technical education and found that the increasing misalignment between societal needs, manifested through industry needs, and the output from technical institutions is a key problem affecting education institutions. The study demonstrated the role of DMAIC in a technical institution for continuously improving student results. The DMAIC method has been progressively used to solve problems in

higher education institutions to reduce cycle time in salary calculations and to improve process consistency (Utecht & Jenicke, 2009).

By implementing DMAIC to improve program-level outcomes, Carnovale *et al* (2016) applied continuous improvement to an online supply chain management program and the results revealed that program and course content could be continuously improved to boost student learning and the desired outcomes. The assessments were done at both program level and course level and necessitated a short-term, project-based approach to quality management which eventually led to improvements in overall program design and delivery. However, there is a lack of research that outlines how DMAIC might be used as a methodology to enhance online assessment.

Background and context

The UoT under study has a learning and teaching strategy that provides a strategic framework for faculties and disciplines for the delivery of optimal learning experience for all students. The strategic framework aims to promote a shared understanding among staff, students and other stakeholders of the mission to deliver excellence in teaching and learning. The UoT acknowledges the inherent complexity of the current environment that is characterised as the fourth industrial revolution. Assessment is an integral part of the teaching and learning process at the UoT and is purposefully and systematically used for identifying, gathering and interpreting information against the required qualification competencies to make an informed judgement concerning a student's achievement. Assessment is perceived as a continuous and iterative process that is used to quantify learning and is also a means of developing lifelong learning and promotion of innovative and creative thinking for consolidating existing learning and building further learning. Additionally, assessment is used by lecturers as a tool for reflecting on the success of teaching strategies.

The UoT's teaching and learning strategy provides a set of approaches and principles that inform teaching and learning in the academic programmes and the university appoints staff with proper qualifications and work experience. The UoT also provides ongoing professional development with focus on several aspects of the scholarship of teaching and learning (SoTL). Similarly, it is imperative that academic staff continually improve their skills, knowledge and competencies relating to teaching and learning. The UoT would encourage academic staff to choose proper teaching methods and promote student learning based on learning outcomes that are linked to assessment. Assessments are primarily used to facilitate learning through opportune and meaningful feedback to students on

assigned formative assessments. The UoT would also require academic staff to participate in the design and review of the programmes in which they teach, since this has a direct bearing on the quality of learning and teaching.

Academic departments use the learning management system (LMS) available for teaching, assessment and various forms of structured learning activities that students undertake under the supervision of the lecturer, or with peers, tutors or as self-directed learning. The institutional e-Learning platform is provided and managed collaboratively and the UoT strives to progressively improve the physical teaching and learning environment by equipping lecture venues with the relevant teaching and learning equipment and technology as well as providing computing and network access. The blended learning approach used by the UoT embraces online classrooms and all staff are encouraged to use Moodle for the management of learning and MS Teams for the delivery and management of online lectures, tutorials and other "contact sessions". Additionally, staff are encouraged to expand this to include options such a Google classroom, WhatsApp messenger services, Facebook and other social media packages. However, from 2020, the COVID-19 pandemic situation has posed unprecedented challenges requiring lecturers to avoid face-to-face contact sessions and adapt to the sole use of online learning and teaching. As a result, many challenges are faced by lecturers in ensuring integrity of online assessments while guaranteeing that learning outcomes are addressed.

Methods and design

Data was collected for one semester from a target population of 500 industrial engineering students. A mixed methods research strategy was used and a sample of 80 participants participated in quantitative data analysis, of whom 40% were female and 60% male. For the qualitative part of the mixed methods research strategy, interviews were conducted with the view to establish reasons for academic dishonesty. Self-selection sampling was adopted, and 15 students volunteered to participate in the study. The advantage of self-selection sampling technique is that it saves time since the researcher does not have to find willing participants, and the participants are more likely to be committed to the study (Hayre, 2021).

The first step of the DMAIC methodology was characterised by defining the problem or opportunity for improvement by fully defining the focus, scope and motivation for the improvement project. The researcher used previous experiences of students' performance in the Production Engineering subject and after consultation with other lecturers, it was established that there was a challenge of a artificially

high pass rate with online assessment during the COVID-19 pandemic at a department of industrial engineering at a UoT.

The second step was to measure student performance in assessments, with the first assessment as the pre-test and the second assessment as post-test after implementing the intervention initiatives. The third DMAIC step was to analyse the process to ascertain the root cause of variation and over-exaggerated student performance. Root cause analysis, through the use of an Ishikawa diagram was deployed to uncover causes of this artificially high pass rate. The major advantage of using root cause analysis is that one would be able to investigate all the potential causes of the problem under investigation. In this case, the standard aspects of an Ishikawa diagram which include material, method, man, technology, measurement and environment were used to investigate the key causes of academic dishonesty. Validity refers to the appropriateness of the tools, data and processes that are used to establish whether the research results obtained meet the research approach requirements (Leung, 2015). The study utilised both criterion and content validity to investigate the key causes of high pass rate.

The fourth step was to improve student performance by addressing and eliminating the root causes of the high pass rate. The Kaizen philosophy is grounded on the notion that existence of waste shows room for continuous improvement, which should be done gradually and continuously, involving all stakeholders. It is process orientated and stresses that the main effort of improvement should come from a new work style and new thinking. Kaizen events were introduced to induce rapid change for improving process performance to obtain realistic test results that reflected actual student performance. The data for assessment results was analysed using Excel Data Analysis Add-in. Paired sample t-tests were used to compare the same sample of students at two different times, which is before and after implementing changes to enhance assessment security and avoid cheating.

The last DMAIC step was to control the improved process and future process performance by developing a quality control plan to document and keep the improved process at its current level. A "pokayoke" is a Japanese term that is used to describe devices that are put in place so that a system does not produce defects or unintended output (Stevenson, 2011). In this case, the essence is to ensure that the Industrial engineering cohorts possess the intended graduate attributes. Pokayokes (mistake proofing) were used to make errors immediately detectable.

Results and discussion

Definition and measurement

Online learning continues to grow as a popular and viable medium for teaching, particularly in the current environment characterised by the Covid 19 pandemic. Despite the fact that many countries are geared towards embracing online learning platforms, due to the inaccessibility of e-learning platforms in some countries, a number of staff and students were thrown in at the deep end of online education, with some students reluctant to readily accept the change from face-to-face instruction (Sibanda & Muyambo, 2020). This case study followed the five-stage DMAIC process presented in the methodology section, and the problem under study was defined as poor integrity of online assessments that causes concern regarding the extent to which learning outcomes were being addressed. Many lecturers initially struggled to transition to online assessment. Measurement was conducted on student performance in assessments.

As highlighted in the previous section, the researcher used previous experiences of students' performance in the Production Engineering subject before the COVID-19 pandemic and after consultation with other lecturers, the scope of the research was formulated. The results suggest that there were challenges with online assessment during the COVID-19 pandemic at this department of industrial engineering. A majority of the students (38%) scored between 80 and 89%, while 31% of the students scored between 70 and 79%. About 9% of the students scored between 90 and 100% while 22% of the students scored between 60 and 69%. No student scored below 60%. These results were higher than 'normal' in this particular module, and it was feared that academic dishonesty may have played a role.

Analysis

The third DMAIC step was to analyse the process and establish the root causes of unrealistic student performance. Academic dishonesty or cheating is a prevalent problem in universities, and interviews were conducted to assess the reasons why the students had all passed the first assessment. The results of these interviews are summarised in Figure 1. The key themes that emerged from the interviews are man, material, method, technology, measurement and environment. These themes emerged deductively, by applying the Ishikawa technique.

The first challenge that emerged relating to people (man) was peer pressure, which would come from a combination of sources such as the self, other students, parents and lecturers. Students might feel pressured to achieve better grades and that would stimulate the incentive to cheat to attain a high pass rate. Parents might desire their children to excel at university, but they would generally not support the notion that their children should cheat to achieve better grades. However, the perception is largely dependent on culture, religious beliefs and social status.
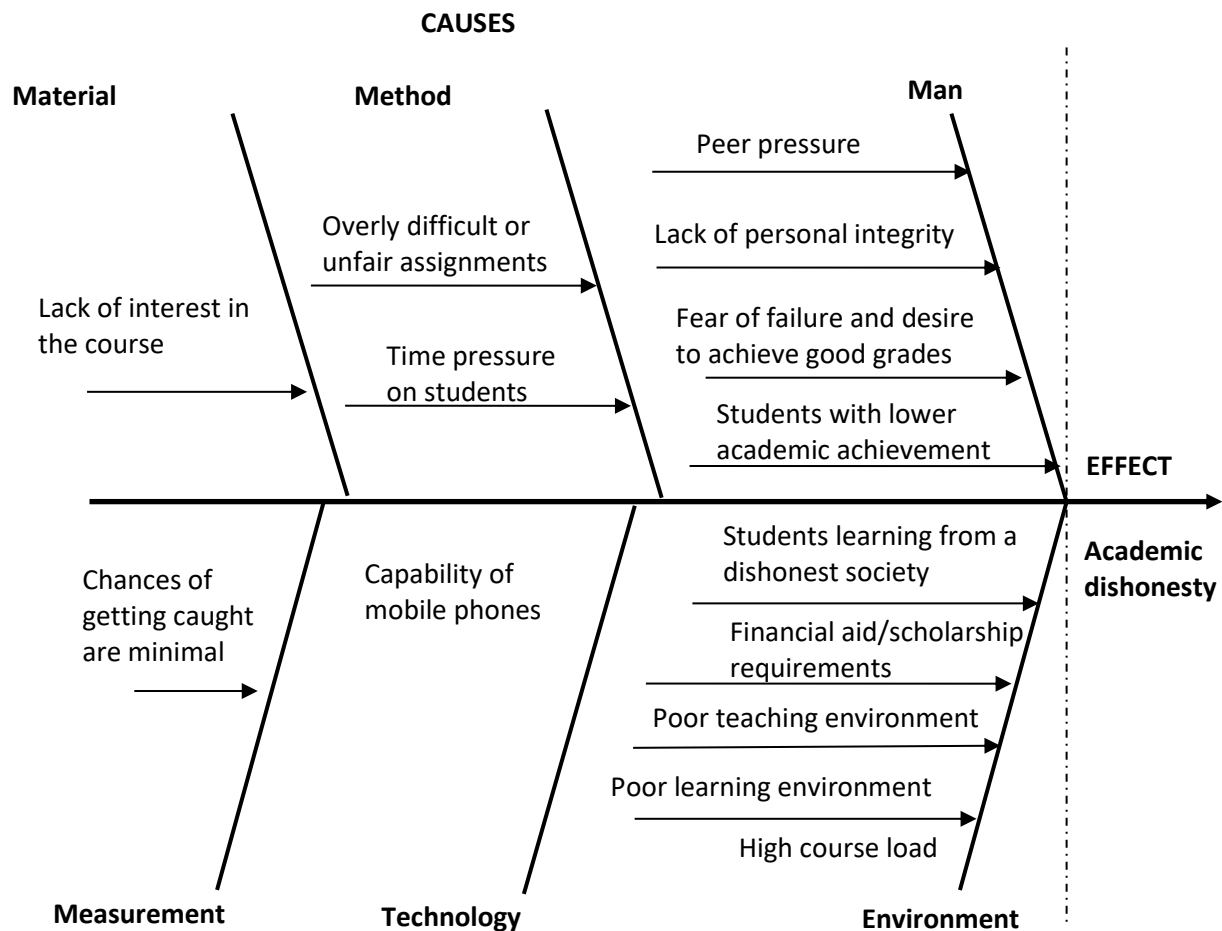
CAUSES

Material   **Method**   **Man**

Peer pressure

Overly difficult or unfair assignments

Lack of personal integrity

Lack of interest in the course

Fear of failure and desire to achieve good grades

Time pressure on students

Students with lower academic achievement

EFFECT

Academic dishonesty

Chances of getting caught are minimal

Capability of mobile phones

Students learning from a dishonest society

Financial aid/scholarship requirements

Poor teaching environment

Poor learning environment

High course load

Measurement   **Technology**   **Environment**

Figure 1: Ishikawa diagram for academic dishonesty in first assessment.

Concerning the "environment" theme, the findings in Figure 1 show that the causes of academic dishonesty include students learning from a dishonest society; financial aid/scholarship requirements; poor teaching environment; poor learning environment and high course load. Students tend to cheat if they experience more pressure to 'do it all', when they get heavy workloads or multiple assessments on the same day. It is critical that academic integrity be emphasised at all levels in an institution of higher learning.

The results on the "technology" theme revealed that capability of mobile phones provides an opportunity for students to cheat in assessments. A student may periodically communicate with other people outside the examination room via email and WhatsApp when writing a test or examination. A student can use a mobile phone camera to capture a snapshot of questions and send as a WhatsApp or an email attachment to somebody for help with answers to an assessment. Additionally, a student can post questions online and receive responses instantaneously from many engines since mobile phones provide internet connectivity. Allowing another person to complete an online test or examination rather than the student who is submitting the work, as well as communicating with other students through the internet to get answers constitutes academic dishonesty.

The causes for academic dishonesty under the "method" theme were found to be overly difficult or unfair assignments as well as time pressures on students. Concerning the "material' theme, the cause for the artificially high pass rate was found to be lack of interest in the course. With regards to measurement, if the chances of getting caught are minimal, then it would motivate the students to cheat thereby compromising the credibility of online academic assessment.

Poor learning environment characterised by students who wrote online test assessments in student residences was also noted as one of the root causes for cheating that might lead to high pass rates. Opportunity occurs for students who reside in university residence when they perceive that they can share answers without being caught.

Improvement

There continues to be much room for improvement in enhancing student online learning experiences while preventing behaviours such as plagiarism, cheating, dishonesty and other academic malpractice. It is imperative that academic lecturers are equipped with procedural support that enhances the management of academic integrity during online assessment and delivery. It is not practical to suppose a universal model for academic integrity policy given that academic integrity policy and practices are not universal (Gamage *et al*, 2020).

The goal of the analysis step was to identify the root causes for academic dishonesty and thereafter continually evolve the process to maximize students' ability to learn and retain knowledge without resorting to academic dishonesty. The fourth step of improvement was characterised by identifying

forms of waste and inefficiencies from the first assessment process. Continuous improvement, or Kaizen events, were initiated to improve process performance to obtain realistic test results that reflected actual student performance. The following measures were implemented to improve the integrity of online tests:

- Displaying the questions one at a time so that it would be difficult to copy questions;
- Using a large pool of questions which were randomized, including randomizing the answer options as well;
- Using random question sets for randomising specific groups of questions;
- Using the "prohibit backtracking" function to avert viewing of previous questions and changing of answers by students;
- Ensuring that the test was not scheduled on the same day as other subjects' tests that students were registered for;
- Setting the Multiple Response Question type to accommodate negative marking to deter students from choosing all options to acquire a full score. Minimum score was set to 0 so that "negative marking" applied to that particular question only;
- Where multi-step problem solving was required, students had to submit their work with a photo of their student ID card on top of the submission;
- Discussing in class the issue of academic integrity to develop students' moral judgment and foster academic honesty.

The provision of resources is also of utmost importance in academic integrity awareness campaigns and information dissemination on academic integrity policy, expectations, practices, disciplinary action and developmental tools for mitigating academic misconduct by students (Prieß-Buchheit, Aro, Demirova, Lanzerath, Stoev & Wilder, 2019). Professional development is crucial for capacity building initiatives for academics so that they are able to detect cases of academic dishonesty.

After implementation of the above measures, measurement was conducted after the second assessment and Figure 2 shows a comparison of student performance on test 1 and 2 assessments. These results demonstrate that there was an improvement in online assessment since the results were more realistic and reflected actual student performance. This assertion is based on the assumption that both test 1 and test 2 were on the same level of complexity since Bloom taxonomy was used to ensure that test 2 was not more difficult than test 1. A majority of the students (38%) scored between 50 and 59%, while 22% of the students scored between 40 and 49%. About 21% of

the students scored between 60 and 69% while 6% of the students scored between 70 and 79%. An overall pass rate of 68% was achieved in the second assessment.
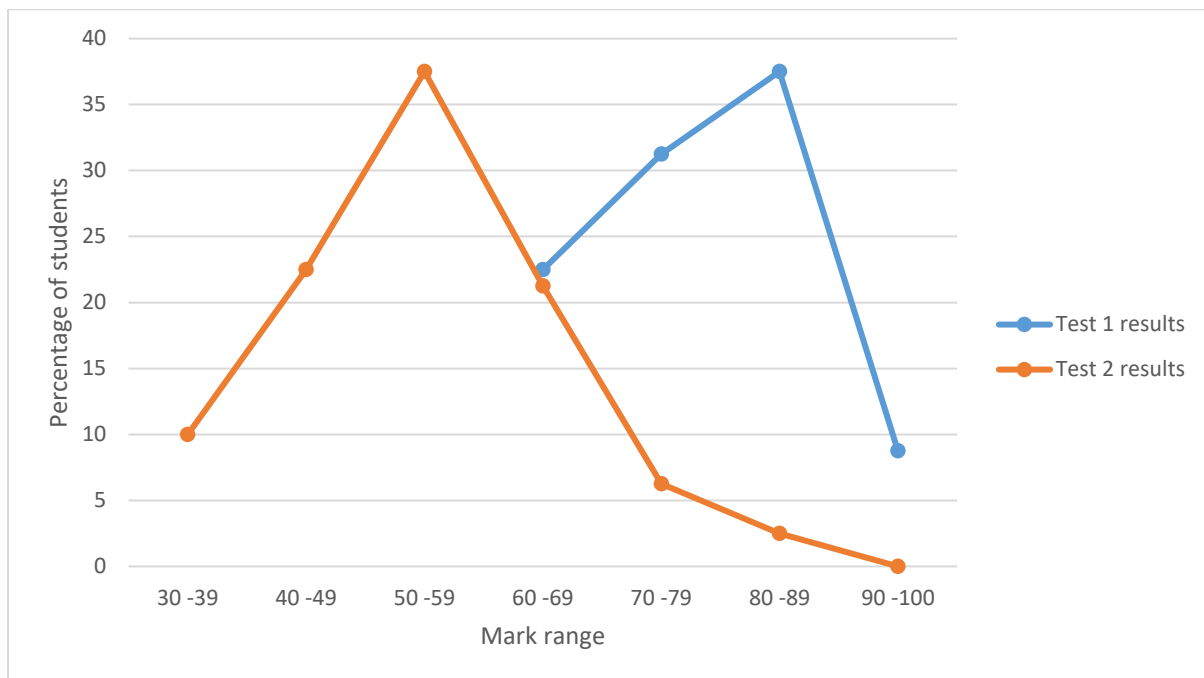

Figure 1: Comparison of student performance on tests 1 and 2.

Paired sample t-tests were then deployed to compare the results of this sample of students for two different tests, which is before and after implementing changes to enhance assessment security and avoid cheating. The paired t test was used to assess if there was a significant difference in the average of the two tests. The hypotheses were expressed as:

H0: μ1 = μ2 ("the paired sample means are equal")

H1: μ1 ≠ μ2 ("the paired sample means are not equal")

Table 1 shows the results obtained, reflecting a very low Pearson Correlation coefficient of 0.171. The mean difference between test 1 and test 2 was found to be statistically significant at α = 0.05. This is because 'Sigma value for (2-tailed)' or $p < 0.05$. Hence, we reject the null hypothesis and accept the alternative hypothesis H1 that the paired sample means are not equal. This is an indication that the measures that were implemented to improve the integrity of online tests had an effect on student performance.

Table 1: T-test - Paired Two Sample for Means.

	Test 1	Test 2
Mean	88.5375	56.425
Variance	100.4036	68.12089
Observations	80	80
Pearson Correlation	0.171996	
Hypothesized Mean Difference	0	
df	79	
t Stat	24.2682	
P(T<=t) one-tail	1.14E-38	
t Critical one-tail	1.664371	
P(T<=t) two-tail	2.28E-38	
t Critical two-tail	1.99045	

Control

The last DMAIC step was to control the measures that had been put in place and ensure future process performance by developing a quality control plan to keep the improved process at its current level. Pokayokes (mistake proofing) such as setting higher cognitive level questions that would not rely on recalling or searching from the Internet yet still aligning with module outcomes were used to reduce or eliminate cheating. The lecturer would use application questions that make it more problematic for students to get answers from the Internet. Google would be used to check questions and adjust the question if Google was providing a solution that would not require the student to display insight to articulate an answer. As part of this quality control plan, students could be verbally requested to outline the steps that they followed to derive an answer to a question to establish if the student was individually responsible for completing the assessment.

In the past, academics in higher education have been unenthusiastic in applying kaizen principles such as DMAIC to academic processes due to misconceptions that these lean principles are primarily tools for manufacturing firms. This case study has demonstrated that continuous process improvement efforts can be deployed to any organisational process with inputs, feedback loops and outputs and DMAIC can radically improve an academic process, where knowledge of these processes is prevalent, such as in an industrial engineering department. It is also worth noting that some of the key causes that emanated from the root cause analysis, through the use of the Ishikawa diagram were beyond control and thus could not be addressed to prevent academic dishonesty. The Kaizen events that were initiated were able to enhance process performance by reducing academic dishonesty and hence, realistic test results that reflected actual student performance were derived.

Conclusion

This paper investigated the factors that inhibit reliability and effectiveness of online assessment in the context of COVID-19. It was highlighted that assessment is pivotal to the teaching and learning process. Hence, assessment is purposefully and systematically used to make an informed judgements about student performance. The results demonstrate that there is room for improvement in the online learning environment, which in turn leads to authentic assessments and better reflection of academic performance by the students. Root cause analysis, through the use of an Ishikawa diagram provided a framework against which assessments were written by students, specifically leveraging the DMAIC framework for structured problem solving and continuous improvement. The study has contributed to the body of knowledge on online assessment. However, the study has limitations since the evaluation focused on only two assessments in one module and future studies could examine more assessments and more modules to validate the generalisability of the results obtained. Furthermore, with the advent of the fourth industrial revolution and with the fifth industrial revolution on the horizon, future research may examine how the ever-changing online teaching and learning technologies may be enhanced to foster academic integrity. Finally, this paper shows how university lecturers might use techniques with which they are familiar to improve their pedagogic practices. This is important given the opacity of much educational literature.

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